



e-ifc No. 23, June 2010

Electronic International Fertilizer Correspondent (*e-ifc*). Quarterly correspondent from IPI.

Editorial

Dear readers,

FAO recently published global cereal production estimates for 2010, which states that 2,286 million tonnes of cereals will be harvested in 2010, increasing by 1.5 percent from last year and similar to the record levels of 2008. The forecasted increase in production will come from “developing countries”, where an increase of 4.8 percent is predicted over the 2009 harvests, while at the same time there will be a 2.4 percent drop in production in “developed countries”. Of course, these predictions will ultimately depend on climatic conditions in the coming months. However, the fact that in some African countries (particularly in Central and Eastern Africa) the increase over 2009 will be around 8 percent is an encouraging forecast. Let us hope that the weather will not negatively impact on this much needed improvement.

Extension is high on the international

development agenda but making a real, substantial improvement in this area is not an easy task. Two interesting publications, which provide some interesting insights, were recently released by the World Bank and FAO (see more on page 25). We at IPI are also striving to increase and enhance our activities in this vitally important area; nevertheless quite a complicated challenge.

In this issue of *e-ifc* you will find the second part of a report from Sudan (the first was published in the previous edition of *e-ifc*) which provides further analysis on the untapped potential for Sudanese agriculture. We also feature a report from India on the supply and balance of soil potassium after twenty years of continuous wheat and sorghum cropping. Potassium concentration in soil as affected by the inputs (potash fertilizer, irrigation water) and outputs (offtake by the crop) is a major focus of

this article. From China, we present a report on the effect of efficient use of potassium on rape seed in one of the major regions for this crop - the Yangtze River Valley (YRV), where productivity and nutrient use efficiency is highlighted. In addition, as always, we bring you updates of events, new scientific publications and more.

I wish you all an enjoyable read.

Hillel Magen

Director

Contents:

Editorial	1
Research Findings	
• Status of Fertilization and Crop Nutrition in Irrigated Agriculture in Sudan 2: Main Crops Consuming Fertilizers and the Role of Education in Optimizing Fertilizer Use	2
• Potassium Balances and Long-Term Sustainability of Sorghum-Wheat in an Alluvial Soil of Haryana, India	7
• Yield Response of Winter Rapeseed to Potassium Fertilization, Use Efficiency and Soil's Potassium Critical Level in the Yangtze River Valley	13
Events	21
New Publications	25
K in the Literature	25
IPI New Coordinator	27
Clipboard	27



Coffee is a major crop in countries of Central America. IPI with the Soil Sci. Soc. of El Salvador (ASCS) conducted a symposium titled *Importancia del Manejo del Suelo y el Potosio en el Desarrollo Agrícola Sustentable de Centroamérica y el Caribe*. Photo by IPI.

Research Findings

Status of Fertilization and Crop Nutrition in Irrigated Agriculture in Sudan 2: Main Crops Consuming Fertilizers and the Role of Education in Optimizing Fertilizer Use

Dawelbeit, S.E.⁽¹⁾, F.M. Salih, O.A. Dahab, and E.H. Ahmed.

Introduction

In Sudan, fertilizers are normally imported. However, the amounts utilized are very low when compared with other parts of the world, including in the Arabian region. Indeed in rainfed farming areas, whether mechanized or traditional, fertilizers are rarely used. The mean annual fertilizer use of N, P₂O₅ and K₂O is very low. According to the FAO (FAOSTAT 2010), in 2006 total consumption was of 44,000, 6,000 and 1,000 mt of urea, superphosphate (above 35 percent) and NPK complex, respectively, mostly used in irrigated agriculture (Table 1). In particular the application of potash is extremely low. Recently, however, a recommended use of 43 kg N ha⁻¹ for sorghum has been approved by the Ministry of Agriculture but for only very localized areas.

Plans to increase fertilizer use are in progress as part of a major government agricultural development executive program for 2008-2011. Cropping areas

are to be increased for crops such as sorghum, cotton, and wheat, and the cultivation of vegetables is to be greatly expanded. It is proposed that fertilizer supplies to the irrigated sector should increase considerably to just over 300,000 tonnes of urea and 50,000 tonnes of triple superphosphate (TSP) supplying all crops including sunflower, sugar cane and rice, besides those mentioned above. If all the areas planned for irrigation come under cultivation, annual fertilizer consumption in the future may increase up to 1,000,000 tonnes.

This paper is the second on the issue of the status of fertilization and crop nutrition in Sudan. The first paper was published in the *e-ife* 22, March 2010 (<http://www.ipipotash.org/eifc/2010/22/2>).

Research conducted with fertilizers on some of the main crops

Soil applied fertilizers

1. Cotton

Cotton is well known historically as an important crop in Sudan and is the major cash crop in the Gezira rotation. Besides export, the crop provides local textile factories with lint, and oil factories with cotton seed. The average yield of seed cotton has generally been low and a number of factors are suspected for this yield restriction including inadequate or inappropriate fertilization. Early investigations (Burhan, 1969, 1971; Burhan and Jackson, 1973; Burhan and Taha, 1974) examined crop response to single-nutrient fertilizers in long-term trials, over 18 seasons, in a 3-4 course rotation. These results showed that:

- The response to 190 kg ha⁻¹ of urea was consistent and significant in all 18 seasons.
- There was an erratic positive response to P as TSP (in about 30 percent of the seasons).



- Response to K was rarely reported.

The fertilization practice adopted in Gezira for cotton production was the application of 86 kg N ha⁻¹ in the form of urea supplied 6 to 8 weeks after sowing followed by green ridging.

In all regions and treatments, the higher dose of fertilizers applied brought higher yields. However, evidence for the relatively poor response of cotton to urea fertilization alone, and sometimes resulting in a negative impact in terms of yield, provided the driving force for research testing of multi-nutrient fertilizers. Results from Ali *et al.* (2002; Table 2), show that when only N was applied, cotton yields were higher when N was supplied as Ammonium Sulfate

Table 2. Akala cotton yield (kg ha⁻¹) in three regions, 2001-2002 (Ali *et al.*, 2002).

Fertilizer	Dose	Gezira	Rahad	N. Halfa
-----kg ha ⁻¹ -----				
Urea	Regular	2,418	2,656	2,383
Urea	Double	2,758	3,098	2,928
AS	Regular	2,928	2,690	3,167
AS	Double	3,133	3,473	3,916
ASN	Regular	2,588	2,622	3,473
ASN	Double	3,269	3,609	3,643
NPK	Regular	2,928	2,622	3,367
NPK	Double	3,814	3,780	3,745

Ammonium Sulfate (AS), 21% N; Ammonium Sulfate Nitrate (ASN), 26% N; and Nitrophoska NPK. (18:18:5).

Table 1. Mean fertilizer nutrient consumption in the irrigated sector, 2000-02 (FAO, 2006).

Fertilizer	N	P ₂ O ₅	K ₂ O
'000 tonnes nutrients			
Urea	54.3		
Triple superphosphate		11.1	
Potassium chloride			3.8

⁽¹⁾Land & Water Research Centre, Agricultural Research Corporation, Wadmedan, Sudan. sdawelbeit2001@yahoo.com.

Research Findings

Nitrate (ASN) or Ammonium Sulfate (AS) in comparison with urea. This finding may result from the greater availability of N in ASN and AS forms and the likelihood of the loss of N from urea by volatilization as ammonia (NH_3). The beneficial effect of the additional P and K on cotton yields over that of N alone is clearly evident from the results of Nitrophoska.

2. Wheat

Wheat production in Sudan started on fertile alluvial soils of the Nile in the Northern and Nile River States where winter is relatively longer and cooler. Since the 1960s, however, wheat production has moved southward and the crop is now cultivated in Gezira, White Nile, Gedarif, Kassala and Darfur States. The recent construction of the Hamadab Dam has also led to an expansion of the area for wheat cultivation. In 2008, wheat was sown on more than 300,000 ha, with an average

productivity of 1.9 mt ha^{-1} (FAOSTAT, 2010).

Ageeb and Abdalla (1988) conducted an on-farm trial where selected treatments of N, P and K combinations were applied to wheat (cultivar Condor) at four different sites in the Gezira Scheme. Phosphorus application significantly increased wheat grain yield in all locations except Dirwish where the site is known to have fertile soil (Table 3). There was no significant response to potassium application indicating that Gezira soil had adequate amounts of available K at that time as previously reported (Finck, 1962). Wheat did not respond significantly to rates of N greater than 86 kg N ha^{-1} in the absence of P application and the response to P application increased from the Central Group (Dirwish and Wad Sulfab) to northern Gezira (Kab El Gidad). The response of wheat to P in El Gadeed Block in Managil Group was similar to that of the northern Gezira. The addition of 43 kg P expressed as $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ increased wheat grain yield by 52 percent over the recommended practice (i.e. 86 kg N ha^{-1}) at Kab El Gidad and El Gadeed. The authors recommended the addition of $43 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ and 86 kg N ha^{-1} to wheat in the Gezira and White Nile Schemes.

3. Sorghum

In Sudan, *Sorghum bicolor* (L.) (Moench) is a staple food crop for more than 75 percent of the population. It is grown all over Sudan in irrigated as well as rainfed areas. Farmers use sorghum straw as animal fodder and rarely apply fertilizers (inorganic or organic) to this crop. In 2008, sorghum was sown on more than 6.6 million ha with an average productivity of 0.5 mt ha^{-1} (FAOSTAT, 2010).

In recent years sorghum yield, even in irrigated schemes, has been declining. For this reason research with multi-nutrient fertilizer has been conducted, in which a NPK complex fertilizer, ASN and AS were compared to urea at Gezira and New Halfa (Abu-Sara *et al.*, 2002; Table 4). A yield increase was observed for the higher dose of the NPK

Table 3. Yield of wheat in response to N, P and K fertilizers in four locations in the Gezira agriculture scheme (Ageeb and Abdalla, 1988).

Treatment (nutrients, kg ha^{-1})	Location / Grain yield (kg ha^{-1})				
	Dirwish	Wad Sulfab	Kab El Gidad	El Gadeed	Mean
	----- kg ha^{-1} -----				
N (129)	4,567	2,347	2,625	1,747	2,822
N (129)	4,741	2,287	2,968	1,468	2,866
NP (43-43)	3,146	2,839	3,249	2,547	2,958
2N;P (86-43)	4,446	3,061	3,982	2,658	3,537
2N;PK (86-43-43)	4,482	3,139	3,929	2,420	3,443
3N; 2.5P (129-64.5)	5,267	3,370	4,353	3,001	3,993
SE (\pm)	257	86	200	93	

A short success story of fertilizer use in the cultivation of wheat in Sudan

Various field research experiments, especially with wheat, have shown that multi-nutrient fertilizers are more effective than a single nutrient supply for nitrogen in increasing yields (Ali, N, *et al.*, 2002 and 2003). This is the case for both on-station and on-farm trials carried out over 1999/2000 and 2000/01 at Gezira, Rahad and New Halfa in order to test the effect of different sources and rates of N on the growth and yield of bread wheat. Both types of trials used different rates of NPK complex fertilizer, ASN and AS. Compared to the control (zero N), the application of the fertilizers resulted in a significant increase in grain yield at the three locations: 51 to 160 percent at Rahad, 39 to 162 percent at Wad Medani, and 13 to 45 percent at New Halfa.

Table 4. Sorghum yield (kg ha^{-1}) in two locations 2000-2002 (Abu-Sara, *et al.* 2002).

Fertilizer	Dose	Gezira	New Halfa
		----- kg ha^{-1} -----	
AS	Single	3,284	3,689
AS	Double	3,784	3,975
ASN	Single	3,380	4,260
ASN	Double	3,879	4,213
Urea; TSP	Double for N	3,444	4,022
NPK 18	Single	3,689	4,308
NPK 18	Double	4,070	4,546

Ammonium Sulfate (AS), 21% N; Ammonium Sulfate Nitrate (ASN), 26% N; and Nitrophoska NPK. (18:18:5).

Research Findings

treatments in both locations, as compared to that of the standard fertilization practice using AS or urea.

4. Sugar cane

In 2008, sugar cane in Sudan was cultivated on more than 60,000 ha (FAOSTAT, 2010). All sugar estates are currently located within the central clay plain which is vertisolic with high clay content. Sugar cane, as a plant crop with successive ratoons, is known to be exhaustive to the soil. It is reported that 100 mt of cane usually removes about 100 kg N, 60 kg P₂O₅ and 150 kg K₂O from the soil (Bekker, 1999). Like other crops, sugar cane requires sufficient quantities of N, P, K, Ca, Mg and S, as well as the microelements viz.: Fe, Mn, Zn, Cu, Mo and B for its growth and development. Nitrogen in the form of urea has been the sole nutrient applied to sugar cane at Guneid for many years. However, N loss to the atmosphere as NH₃ may occur following urea application to the soil and its subsequent hydrolysis to ammonium carbonate, as reported by Tisdale and Nelson (1975).

Two experiments to evaluate the effects of other N forms were conducted by Awad *et al.* (2004) using the variety (Co6806) for two plant crops and their successive first ratoons at El Gunied sugar cane research farm over two successive seasons. The efficiency of the two fertilizer forms applied, namely ASN and Nitrophoska (NPK 18:18:5), were compared with the standard fertilization practice (4.5 N urea + 2P TSP). The results of cane and sugar yield were statistically analyzed and economically evaluated (Table 5). The results reveal that the plant crop responded well to the lower dose (2.25 N) of the two tested fertilizers, while the ratoon crop responded better to the higher dose (4.5 N) of the fertilizers. This disparity is due to the fact that the plant crop is normally preceded by a fallow, thus improving the soil residual nitrogen. Based on yield data for both tested fertilizers, the lower dose (2.25

Table 5. Sugar yield (kg ha ⁻¹) for the two plant crops and their first ratoons (Awad, <i>et al.</i> 2004).					
Fertilizer	Dose	Plant crop season I	Plant crop season II	Ratoon crop season I	Ratoon crop season II
-----kg ha ⁻¹ -----					
ASN	2.25	14,661	15,184	11,828	11,353
ASN	4.5	15,589	15,018	11,329	13,257
Urea; TSP	4.5 N; 2P	12,685	14,970	10,448	10,472
NPK	2.25 N	13,923	16,303	11,852	12,923
NPK	4.50 N	14,994	15,541	13,614	12,781
Mean		14,804	15,399	11,805	12,162
SD (+/-)		0.26	0.21	0.43	0.45
Ammonium Sulfate (AS), 21% N; Ammonium Sulfate Nitrate (ASN), 26% N; and Nitrophoska NPK. (18:18:5).					

N) is recommended for the plant crop and the higher dose (4.5 N) is recommended for the first ratoon crop for sugar cane production at the testing site.

5. Vegetables

The two economic vegetables in Sudan are onion and tomato (Abu-Sara, 2001), which are produced under two production systems. The first system includes riverbank sites, the high lands of west Sudan and the sedimentary deltas in east Sudan which all provide light alluvial or volcanic soils that are characterized by moderate pH and high fertility. The second system is under the irrigated central clay plain, viz. Gezira and Rahad schemes. Vegetable yield is relatively low in these schemes as compared to the average yield across Sudan (Faki *et al.*, 1994) and similar production systems in Africa. For optimum and economic yield balanced fertilization regimes have been adopted. In 2008, vegetables were grown on more than 330,000 ha (FAOSTAT, 2010).

a) Onions

Onion is the most important economic vegetable in Sudan occupying about 33 percent of the total area under vegetables. Around 273,000 bulbs are produced each year, representing about 25 percent of the country's total vegetable production (Ahmed, 1994).

Onion yield under the first type of production system is high, ranging from 14.3 to 30 tonnes ha⁻¹ on the high lands of west Sudan (Abu-Sara *et al.*, 2001b) compared to the average yield in country, which is 12.4 tonnes ha⁻¹. Field experiments were carried out by Abu-Sara *et al.* (2001b) to evaluate yield response of onion to different sources and rates of nitrogen for the seasons (1999-2001) under the conditions at the experimental research farms at Rahad, Gezira and Sennar. Significant yield responses were detected between treatment means at Rahad and Gezira, while the response was insignificant at Sennar.

b) Tomatoes

Tomato is the second most important economic vegetable in Sudan occupying about 28 percent of the total area, annually producing about 294,000 tonnes, which represents around 27 percent of the country's total vegetable production (Ahmed, 1994). The effect of different sources and rates of N on the yield performance of tomato at Rahad and the Gezira research farm were evaluated (Abu-Sara *et al.*, 2001a). Highest yields were produced by treatments of 130 kg ha⁻¹ N in NPK and 86 kg ha⁻¹ N in ASN, as compared to the standard treatment (86 kg ha⁻¹ N as urea +43 kg ha⁻¹ P as TSP). At the Gezira research farm, 96 kg ha⁻¹ of N in

Research Findings



Photo 1. Farmer Field Schools. Photo by Ahmed Hassan. 2002. (ARC).



Photo 2. Methods of fertilizer application are practiced in extension training programs. Photo by Ahmed Hassan. 2002. (ARC).

the form of an NPK complex and AS produced the highest yields. Significant yield differences between the sources and rates of N were obtained in both seasons.

The role of education in optimizing fertilizer use

The role of education has not been evaluated specifically; however the effect of training has been evaluated from two projects.

The first was a FAO fertilizer program project (1996), which was conducted during the period of 1977-1990, to assist the Government in attaining its goals for increasing agricultural productivity, particularly among small-scale farmers. The overall immediate objective was to raise crop yields. The

approach to achieving these aims was:

(a) To improve accessibility of both quantity and quality of fertilizers and related inputs to farmers at suitable places and times.

(b) To provide the farmers with information about adequate fertilizer recommendations and related improved practices.

Training was given at several levels: A high level of assistance in project management was provided to ensure sustainability in project activities at extension level and at input supply level. Field trials involving demonstrations to refine fertilizer recommendations were set up. In this work, training was given both to project supervisors and farmers. Farmers were trained in one-day sessions in the field throughout the agricultural seasons. Training was also

carried out at the extension unit, in a village or at a field demonstration site. As a result of this approach, fertilizer consumption increased during the last six years of the project, especially at the small-scale farmer level. The training provided under the project represents a big achievement in general

human resource development. However, this is only a start and it is clear that training must be continued, intensified, and be introduced to areas not yet reached by these project activities.

A second example was a scheme which was introduced to raise productivity by broadening farmers' choice through farming systems and water management (Ahmed and Mohamed, 2000-2002). This project was conducted during 2000-2002 and the effect of fertilizers was evaluated indirectly through the overall training. The project was carried out in the Abed Hakam area in the Gezira Scheme. Training of farmers was at the core of project activities, which included participation in training and extension through farmer field schools (FFSs). Seven Master Training Workshops (MTWs) were carried out in which the training needs in the FFSs and Rural Women Schools (RWSs) were reviewed. A training curriculum for the training of trainers (TOTs) was then developed; each MTW was followed by a TOT lasting for four days. Training to demonstrate the effect of fertilizer on crop growth is shown in Photo 1. Methods of fertilizer application either through placement or broadcasting are illustrated in Photo 2.

This project resulted in considerable progress in increasing crop productivity and cropping intensity. The intensive training program over the period of the

Annex: Fertilizer Recommendations for some major crops.

Crop	Recommendation (N-P ₂ O ₅ -K ₂ O, kg ha ⁻¹)	Location
Cotton	86-0-0	Gezira
Wheat	86-43-0	Gezira, North Sudan
Sorghum	(86-43)-0-0	Gezira, rain-fed area
Sugar cane	172-0-0	Kenana sugar estate
Rice	129-43-0	Abu Naama, Gezira
Kenaf	86-0-0	Abu Naama, Khashm El Girba
Maize	86-43-0	Irrigated Agriculture
Sunflower	(86-43)-0-0	Gezira, Rahad
Onion	86-0-0	Gezira, Rahad
Tomato	86-0-0	Gezira, Rahad

Research Findings

project raised the awareness of the farmers to the benefits of improved cultivation practices and to the need for greater cooperation between the farmers themselves. Moreover, the combination of higher crop yield with the increases in total areas cropped contributed to the improvement of the farmers' wellbeing as a whole making them more responsive to participation.

In another training program, the farmers participated in a course on "Integrated Pest Management in Vegetables, Wheat and Cotton in Sudan 1997", which considered best production practices and chemical protocols in improving yield. The effect of this training on fertilizer use by the farmers was documented and its benefits are convincing from a comparison of those farmers who took part in the project and their neighboring farmers who did not. Both groups grew tomatoes, and although the participating farmers used lower amounts of inorganic fertilizer (urea) they obtained higher yields, with net average profits more than 100 percent greater than the neighboring farmers who received no training.

Acknowledgments

The authors appreciate the contribution of Dr. Ahmed H. Mohamed for providing all the photos, which add value to the text.

References

- Abu-Sara, A.F., A.A. Abedel Rahim, and M.A.M. Idris. 2001a. Yield response of tomato to different forms of nitrogen fertilizers in the central clay plain of Sudan. Proceedings of the crop husbandry committee, October 2001. ARTC, Wad Medani, Sudan.
- Abu-Sara, A.F., A.E. Khashmelmous, A.O.S. Abdel Rahim, A.A. Hashim and M.A.M. Idris. 2001b. Yield response of onion to different forms of nitrogen fertilizers in the central clay plain of Sudan. Proceedings of the crop husbandry committee, October 2001. ARTC, Wad Medani, Sudan.
- Abu-Sara, A.F., N.A. Ali, A. Babiker, M. Saeed, K. Hamid, A.A. Hashim and M.M.A. Idris. 2002. Response of sorghum to different form of fertilizers and nitrogen level in some irrigated schemes of the central clay plain of Sudan. A paper submitted to the crop husbandry committee. Land and Water Research Centre, ARC. Wad Medani, Sudan.
- Ageeb, O.A.A., and H.H. Abdalla. 1988. Researcher-managed trials: The response of wheat to NPK fertilizers in farmers' field in Gezira. Paper presented at Third Wheat coordination meeting, 4-6 September 1988, ARC, Wad Medani, Sudan.
- Ahmed, M.K. 1994. Factors affecting productivity of vegetable crops in Sudan. In Z.T. Dabrowski, (eds.) Integrated vegetable crops management in Sudan. ICIPE Science Press, Nairobi, Kenya, p. 12-15.
- Ali, N.A., A.A. Hashim, E.A. Babiker, M. Saeed, M.A.M. Idris, and A.M.A. El Hassan. 2002. Response of irrigated cotton to fertilizer form and rate. A paper submitted to the crop husbandry committee. Land and Water Research Centre-ARC, Wad Medani, Sudan.
- Ali, N.A., M. Saeed, K. Hamid, A.E.M. Elamin, A.F. Abu Sara and M.M.A. Idris. 2003. Effect of fertilizer form on wheat production in Gezira and New Halfa. A paper submitted to the crop husbandry committee. Land and Water Research Centre-ARC. Wad Medani, Sudan.
- ARC Crop Husbandry Committee reports. 2004-2007.
- Awad, E.M., N.A. Ali, E.M.E. Abbass, and M.A. Abana. 2004. Effect of different fertilizers form on sugar yield at El Guneid Sugar Scheme. Crop husbandry committee 2004. ARC, Wad Medani, Sudan.
- Bekker, H. 1999. Sugarcane cultivation and management. Kluwer Academic publisher, p. 155-157.
- Burhan, H.O. 1969. Rotation responses of cotton in the Gezira. In Siddeg, M.A., and L. Hughes, (eds.) Cotton growth in Gezira environment, p. 51-57.
- Burhan, H.O. 1971. Responses of cotton to levels of fertilizer nitrogen in the Sudan. Cott. Grow. Rev., p. 116-127.
- Burhan, H.O., and J.E. Jackson. 1973. Effects of sowing date nitrogenous fertilizer and insect pest control on cotton yield and its year-to-year variation in the Sudan Gezira. Journal of Agricultural Science, p. 481-389.
- Burhan, H.O., and M.A. Taha. 1974. Effect on New cotton varieties of sowing date, plant population and time of fertilizer application. Cott. Grow. Rev., p. 177-186.
- Faki, H., A.T. Ahmed, and A. Elsaffar. 1994. KAP survey on vegetables production in Gezira and Rahad Schemes and private farms along the Blue Nile. In Dabrowski, Z.T., (eds.) Integrated vegetable crop management in Sudan. ICIPE Science Press, Nairobi, Kenya, p. 49-71.
- FAO. 2006. Fertilizer use by crop in the Sudan. Food and Agriculture Organization of the United Nations, Rome. TC/D/A0416E/1/2.06/300.
- FAOSTAT 2010. Accessed May 2010.
- Finck, A. 1962. Kalium status of some Sudan clay soils. Plant and Soil 16(3):293-311.
- Tisdale, S.L. and W.L. Nelson. 1975. Soil fertility and fertilizers. Macmillan publishing, p. 122-155. ■

The paper "Status of Fertilization and Crop Nutrition in Irrigated Agriculture in Sudan 2: Main Crops Consuming Fertilizers and the Role of Education in Optimizing Fertilizer Use" appears also at:

[Regional Activities/WANA](#)

Research Findings

Potassium Balances and Long-Term Sustainability of Sorghum-Wheat in an Alluvial Soil of Haryana, India

Singh K., and S.K. Bansal⁽¹⁾.

Introduction

Potassium exists in four forms in soil: water soluble, exchangeable, non-exchangeable, and structural or mineral form. Equilibrium and kinetic reactions between these four forms of soil K determine the contribution of each soil K form in supplying growing crop plants via K from soil solution (Sparks and Huang, 1985). In alluvial soils in which mica is found as a dominant mineral, a substantial quantity of K is released from the mineral structure which provides most of the K taken up (Singh *et al.*, 2007). This release of K, however, is probably inadequate to sustain long-term crop cultivation and there is a need to investigate the contribution that it provides. A long-term field study was therefore carried out growing sorghum and wheat supplied with different levels of K fertilizer (and N and P) on an illite dominant Inceptisol soil of Southern Haryana. This experiment had three objectives: i) to quantify long-term K contribution of each soil K form to growing sorghum and wheat; ii) to quantify long-term K release from the structural form; and iii) to assess the effect of K release from structural soil K on long-term sustainability of growing sorghum and wheat.

Materials and Methods

A potassium balance sheet was drawn up using inputs including fertilizers, farmyard manure and irrigation water,

and output through crop offtakes and soil K status in different treatments after 20 crop cycles in a long-term experiment which was started in 1985 on a loamy sand Udic Haplustept at the Potash Research Institute of India (PRII), Gurgaon, Haryana, India, involving a sorghum (fodder)-wheat cropping system. Both crops were irrigated occasionally to compensate for lack of precipitation.

Soil

The major feature of this experiment was the K status of the soil on which the long-term field experiment was carried out, an illite dominated Inceptisol containing substantial amounts of K in mineral form. The initial chemical and physical characteristics of this soil, as well as the irrigation water used in 1985, are given in Table 1.

The soil with almost 80 percent sand, and about 10 percent silt and clay developed on alluvial parent material. Mica was present in all three fractions and was also the dominant mineral in the silt fraction in which K feldspars were present as an associate mineral. The clay fraction consisted of 40 percent illite, 15 percent vermiculite, 25 percent chlorite, 14.5 percent kaolinite, 5 percent amorphous material and 10 percent feldspar+quartz (Sekhon *et al.*, 1992). The pH of the soil was slightly alkaline and had a normal value of electrical conductivity. The soil for this long-term experiment was



Project location in India.

medium in both 1N NH_4OAc (water soluble and exchangeable K) and boiling 1N HNO_3 K (non-exchangeable K) in 1985, and had low organic carbon status (Table 1), but the soils of the area were considered to be a good supplier of K to growing crops. NH_4OAc -K, which includes water soluble and exchangeable

Table 1. Initial (1985) properties of the Udic Haplustept long-term experiment and average (140 irrigations) chemical composition of ground water used to irrigate sorghum and wheat in 20 crop cycles.

Parameter	Unit	Value
Soil (0-15 cm)		
pH (1:2)		8.2
EC (1:2)	dSm^{-1}	0.19
Organic Carbon	(mg kg^{-1})	2.37
CEC	$(\text{cmol}(\text{p}^+)\text{kg}^{-1})$	4.20
Sand	%	79.6
Silt	%	9.4
Clay	%	11.0
Texture		Loamy-sand
Classification		Udic Haplustept
Bulk Density	(Mg m^{-3})	1.48
Saturated Hydraulic-Conductivity	(cm h^{-1})	4.5
Alkaline $\text{KMnO}_4 - \text{N}$	(mg kg^{-1})	63.5
Olsen P	(mg kg^{-1})	2.4
1N NH_4OAc -K	(mg kg^{-1})	75.1
Non-exchangeable K	(mg kg^{-1})	773
Water		
pH		7.65
EC	(dSm^{-1})	1.15
Ca+Mg	(meq l^{-1})	5.50
Na^+	(meq l^{-1})	5.58
K^+	(mg l^{-1})	3.90
CO_3^{2-}	(meq l^{-1})	ND
HCO_3^-	(meq l^{-1})	6.4
SO_4^{2-}	(meq l^{-1})	ND
Cl^-	(meq l^{-1})	4.9
NO_3^-	(mg l^{-1})	22.5
SAR	$(\text{meq l}^{-1})^{0.5}$	3.37
RSC	(meq l^{-1})	0.9

⁽¹⁾Potash Research Institute of India (PRII); Sector-19, Gurgaon 122001 (Haryana) India. surinkumar@yahoo.co.in

Research Findings

K₂O was determined according to Hanway and Heidel (1952).

Long-Term field experiment

In the field experiment there were seven treatment combinations with three levels of N (0, 120 and 240 kg ha⁻¹ crop⁻¹), two levels of P (26.2 and 52.3 kg ha⁻¹ crop⁻¹) and three levels of K (0, 49.8 and 99.6 kg ha⁻¹ crop⁻¹). Each treatment was given to both wheat (in winter) and sorghum (in summer) (Table 2). These treatments were replicated three times in a randomized block design. Three levels of K (0, 49.8 and 98.8 kg ha⁻¹ crop⁻¹) were applied along with the optimum recommended doses of 120 kg N and 26.2 kg P, two levels of K (0 and 99.6 kg K ha⁻¹) were applied at high doses of 240 kg N and 52.3 kg P. The doses of 120 kg N, 26.2 kg P and 49.8 kg K were integrated with 10 tonnes farmyard manure. The farmyard manure used in this experiment contained 0.5 percent K, equivalent to 50 kg K ha⁻¹ year⁻¹ in each wheat and sorghum.

During the period of 20 crop cycles, the sorghum was sown in the last week of June and harvested in the first week of September as a fodder crop, while wheat was sown in mid November and harvested in the second week of April. The full dose of P and K with half of the dose of N was applied at sowing time, and the remaining half dose of N was applied after the first irrigation in both crops. A uniform dose of 10 kg Zn ha⁻¹ year⁻¹ was also applied in the form of zinc sulfate heptahydrate. The sources of N, P and K were urea, di-ammonium phosphate (DAP) and potassium chloride (MOP), respectively.

During the 20 crop cycles, 140 irrigations - each having 7.5 cm depth - was applied using underground water. The average (of 140 irrigations) chemical composition of underground water used in irrigation is given in Table 1. Total K contribution from underground water was computed by

Table 2. Treatments of the long-term fertilizer experiment, 1985-2005.

Treatment	Nutrient level
	kg ha ⁻¹
Control	0
N ₁ P ₁ K ₀	120-26.2-0
N ₂ P ₂ K ₀	240-52.3-0
N ₁ P ₁ K ₁	120-26.2-49.8
N ₁ P ₁ K ₂	120-26.2-99.6
N ₂ P ₂ K ₂	240-52.3-99.6
N ₁ P ₁ K ₁ +FYM	120-26.2-49.8+10 mt FYM

Note: P and K are represented in their elemental forms.

multiplying the amount of water applied by the average K concentration of water applied in 20 crop cycles.

Harvested plant samples were weighed then oven-dried at 70°C to constant weight and ground to a fine powder. Measurement of K was carried out by the standard method of flame photometry following acid digestion (HCl-HNO₃).

Total K offtake by wheat and sorghum in 20 crop cycles was calculated by multiplying the K content in fodder for sorghum and grain and straw for wheat by their respective yields. K contribution from different forms of soil K was assessed by taking into account the changes in 1N NH₄OAc-K, and non-exchangeable K in 20 crop cycles. K released from the structural form of soil

K was calculated using the following formula:

$$tKr = tK \text{ off} - \text{depinsoil} + \text{bupinsoil} - K \text{ added}$$

tKr = total K released in 20 crop cycles from the structural form of soil K (kg K ha⁻¹); tK off = total K removed by wheat and sorghum in 20 cycles (kg K ha⁻¹); depinsoil = net depletion in NH₄OAc and non-exchangeable K status of soil in 20 cycles (kg K ha⁻¹); bupinsoil = net build up in NH₄OAc and non-exchangeable K status of soil in 20 cycles (kg K ha⁻¹); K added = total amount of K added in 20 cycles through fertilizer, manure and from irrigation water (kg K ha⁻¹). Leaching and deposition of K were neither measured nor calculated in this experiment.

Results and Discussion

Wheat yields

Cumulative wheat grain yield over the 20 years presents a different picture from sorghum (Fig. 1). Cumulative wheat grain yield in the control was only 18.1 mt ha⁻¹ which increased five fold to 94.9 mt ha⁻¹ by NP application with N₁₂₀P_{26.2}K₀. Application of 49.8 kg ha⁻¹ crop⁻¹ year⁻¹ in N₁P₁K₁ produced a cumulative wheat grain yield of 103.1 mt ha⁻¹ which works out to be a response of about 9 percent for the K applied. Applying a higher dose of K (99.6 kg K ha⁻¹ year⁻¹) with N₁₂₀P_{26.2} did

Table 3. Offtake of K by wheat and sorghum in 20 crop cycles.

Treatments kg ha ⁻¹ crop ⁻¹	Wheat			Sorghum	Total
	Grain	Straw	Total		
N ₀ P ₀ K ₀	107	536	643	947	1590
N ₁₂₀ P _{26.2} K ₀	484	1,497	1,981	1,131	3,112
N ₂₄₀ P _{52.3} K ₀	497	1,154	1,651	632	2,283
N ₁₂₀ P _{26.2} K _{49.8}	557	2,352	2,909	1,546	4,455
N ₁₂₀ P _{26.2} K _{99.6}	561	2,835	3,396	2,592	5,988
N ₂₄₀ P _{52.3} K _{99.6}	585	3,099	3,684	2,047	5,731
N ₁₂₀ P _{26.2} K _{49.8}	568	2,818	3,386	2,177	5,563
+10 mt FYM					
C.D (P≤0.05)	55	154		145	

Research Findings

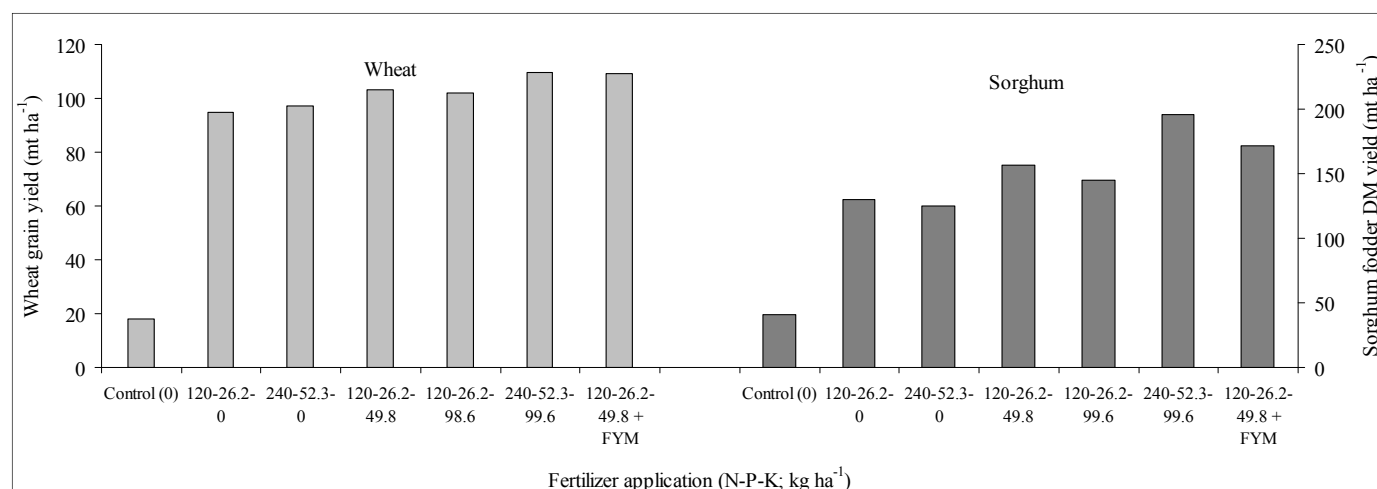


Fig. 1. Cumulative grain yields of wheat and DM of sorghum over 20 years (1985-2005).

not show any benefit as the cumulative grain yield was only 102 mt ha⁻¹. However, applying 10 mt FYM with the N₁₂₀P_{26.2}K_{49.6} treatment produced a cumulative grain yield of 109.2 mt ha⁻¹ which was on a par with that of the N₂₄₀P_{52.3}K_{99.6} treatment (109.8 mt ha⁻¹), showing the greater advantage of FYM application for the grain crop of wheat as compared to that of the fodder crop of sorghum. Application of the N₂₄₀P_{52.3}K_{99.6} treatment produced 109.8 mt ha⁻¹ of cumulative wheat grain yield which was about 12.8 percent more than for the N₂₄₀P_{52.3}K₀ treatment (97.3 mt ha⁻¹).

Sorghum yields

Cumulative crop yields of sorghum (fodder) dry matter (DM) and wheat grain over the 20 crop cycles are shown in Fig. 1. Cumulative sorghum DM yield in the control (N₀P₀K₀) was 40.7 mt ha⁻¹, which rose to 130.1 mt ha⁻¹ in the N₁₂₀P_{26.2}K₀ treatment and increased further by about 12 percent to 156.7 mt ha⁻¹ by the additional application of 49.8 kg K ha⁻¹ crop⁻¹ year⁻¹ (treatment N₁₂₀P_{26.2}K_{49.8}). Doubling the application of N and P, but without K, (N₂₄₀P_{52.3}K₀) reduced the sorghum DM yield to 125.4 mt ha⁻¹. The highest cumulative yield of 196 mt ha⁻¹ was obtained by doubling

the application of K to 98.6 kg K ha⁻¹ crop⁻¹ year⁻¹ together with the doubled N and P (N₂₄₀P_{52.3}K_{99.6}). This led to an increase of about 56.8 percent in DM yield over that without K, (N₂₄₀P_{52.3}K₀). The treatment with 10 mt FYM associated with low levels of N, P, and K application in the form of mineral fertilizers did not compensate for the lower amount of mineral fertilizer nutrients applied and DM yields were correspondingly lower than in the N₂₄₀P_{52.3}K_{99.6} treatment.

Application of FYM differs in its effect on wheat grain yield and dry matter yield of vegetative sorghum. For wheat application of FYM, together with relatively low levels of NPK (N₁₂₀P_{26.2}K_{49.8}), may be sufficient for sustainable production, whereas for high sorghum fodder yields, it is essential to apply twice as much mineral fertilizer as N, P and K, (N₂₄₀P_{52.3}K_{99.6}), with the benefit of additional FYM seen only at the lower mineral fertilizer application rate (N₁₂₀P_{26.2}K_{49.8}).

Potassium offtake for wheat

Potassium offtake in the various treatments varied greatly and for the whole cropping system (including sorghum and wheat) increased almost four-fold as compared to the control (Table 3). For wheat, potassium offtake

tripled after fertilizing with N and P (N₁₂₀P_{26.2}K₀) as compared to the control, demonstrating the effect of increased K offtake just by applying N and P. The magnitude of increase in offtake by grain and straw was similar: K offtake by grain increased from 107 to 484, and that of straw from 536 to 1497 kg K ha⁻¹. Adding K fertilizer (N₁₂₀P_{26.2}K_{49.8}) significantly increased K offtake, mostly in the straw. Highest K offtake in wheat was in the treatment that achieved the highest yield with high K (N₂₄₀P_{52.3}K_{98.6}) at 3,684 kg K offtake over 20 years.

Potassium offtake for sorghum

Similar to wheat, application of N and P (compared with the control) increased yields and hence also K offtake but at a much lower magnitude (2.5 fold). Highest K offtake by sorghum was at N₁₂₀P_{26.2}K_{99.6}. However, this treatment was not the best in terms of DM production.

Potassium status in soil

Increase in the exchangeable potassium was evident only with the high K applications (K_{99.6}) in both horizons or with FYM for the A horizon (A – 0-15 cm and B – 15-30 cm; Table 4). In general, exchangeable K in the upper

Research Findings

Table 4. Changes in 1N NH₄OAc-K (water soluble plus exchangeable K) and non-exchangeable K status of the Udic Haplustept over 20 crop cycles.

Treatments N-P-K	1N NH ₄ OAc K status and change							Non-exchangeable K status and change						
	1985		2005		Delta 2005-1985			1985		2005		Delta 2005-1985		
	A	B	A	B	A	B	Total	A	B	A	B	A	B	Total
<i>kg ha⁻¹ crop⁻¹</i>	<i>kg ha⁻¹</i>													
N ₀ P ₀ K ₀			147	112	-22	-14	-36			1,772	1,559	-137	+56	-81
N ₁₂₀ P _{26.2} K ₀			103	99	-66	-27	-93			1,570	1,636	-339	+133	-206
N ₂₄₀ P _{52.3} K ₀			104	97	-65	-29	-94			1,512	1,577	-397	+74	-323
N ₁₂₀ P _{26.2} K _{49.8}	169	126	141	109	-28	-17	-45	1,909	1,503	1,785	1,652	-124	+149	+25
N ₁₂₀ P _{26.2} K _{99.6}			206	140	+37	+14	+51			1,897	1,817	-12	+314	+302
N ₂₄₀ P _{52.3} K _{99.6}			198	109	+29	-17	+12			1,747	1,622	-162	+119	-43
N ₁₂₀ P _{26.2} K _{49.8}			172	107	+3	-19	-16			1,759	1,696	-150	+193	+43
+10 mt FYM														
C.D (P≤0.05)	NS	NS	36	9				NS	NS	77	121			
<i>Note:</i> A=0-15 cm; B=15-30 cm.														

Note: A=0-15 cm; B=15-30 cm.

horizons (0-15 cm) were depressed more than the 15-30 cm, whilst changes in exchangeable K were from -94 to +51 kg ha⁻¹ during the period 1985-2005.

Non-exchangeable K showed depletion of K in the A horizon (0-15 cm) but build up of K in the B horizon, yet, the total calculation for the 0-30 cm showed decline in non-exchangeable K in most of the treatments (Table 4). Non-exchangeable form of soil K is held between adjacent tetrahedral layers of dioctahedral and trioctahedral mica, and is only moderately to sparingly

available to crop plants (Sparks and Huang 1987). In 20 cycles, this form of soil K contributed 6.62 percent K to the total K removed by sorghum and wheat, which were grown with the recommended doses of N and P (N₁₂₀P_{26.2}K₀) (Table 3 and Fig. 2). This K contribution was attributed to net 206 kg K ha⁻¹ decrease in value of this form, both at surface and subsurface layers of plots receiving the treatment N₁₂₀P_{26.2}K₀ (Table 4).

Negative changes in exchangeable and non exchangeable K in soil occurred in conjunction with low yields and K

offtake (Fig. 1 and 2) which were with the zero K treatments. Application of K in any of the treatments dramatically changes the soil K balance (Fig. 2).

The above findings show that K released from the structural form was unable to sustain sorghum and wheat productivity at optimum levels. Consequently, both sorghum and wheat responded significantly to applied K fertilizer; sorghum responding to a greater extent in comparison to wheat (Fig. 1). Sorghum, owing to its shallow root system, only absorbs K from the surface layers of the soil, whereas

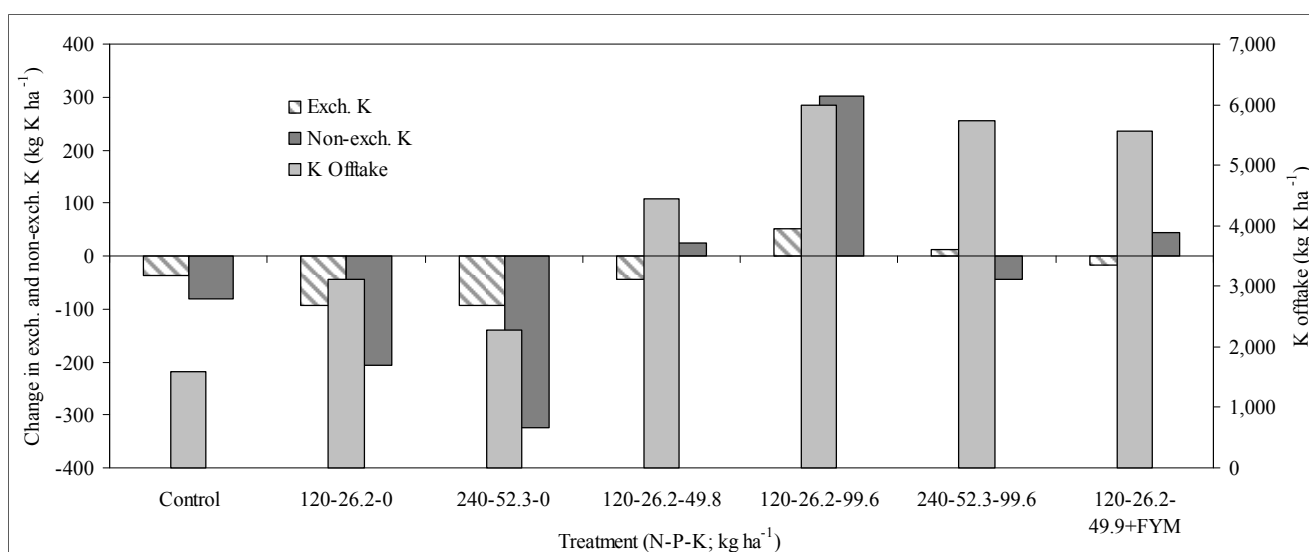


Fig. 2. Change in exchangeable and non-exchangeable K and K offtake during 1985-2005.

Research Findings

wheat, on the other hand, absorbs K from the surface and subsurface layers due to its deep root system. For this reason, greater responses to applied K fertilizer were found in sorghum rather than wheat.

Exchangeable K forms of soil, contributed 3 percent K, and non-exchangeable K form contributed 6.6 percent K to the total K removed by sorghum and wheat over 20 crop cycles. Ground water used in irrigations contributed 13.1 percent K. The contribution of soil K forms to growing sorghum and wheat including the K release from the structural form, decreased significantly with the K fertilizer application to the growing crops.

Table 5. Balance of K between the various sources (1985-2005).

Treatments	Output of K ⁽¹⁾ Total K offtake by the crops	Inputs of K by sources ⁽¹⁾ (depinsoil + bupinsoil)				Net depletion of soil K from structural K ⁽²⁾ (tKr)
		Irrigation water	Fertilizer	Soil water soluble & exchangeable K	Soil non-exchangeable K	
<i>kg ha⁻¹ crop⁻¹</i>						
N ₀ P ₀ K ₀	1590	409	0	36	81	1064
N ₁₂₀ P _{26.2} K ₀	3112	409	0	93	206	2404
N ₂₄₀ P _{52.3} K ₀	2283	409	0	94	323	1457
N ₁₂₀ P _{26.2} K _{49.8}	4455	409	1992	45	0	2034
N ₁₂₀ P _{26.2} K _{98.6}	5988	409	3984	0	0	1948
N ₂₄₀ P _{52.3} K _{98.6}	5731	409	3984	0	43	1307
N ₁₂₀ P _{26.2} K _{49.8}	5563	409	3992	16	0	1189
+10 mt FYM						

⁽¹⁾Analyzed; ⁽²⁾Calculated

Potassium balance

Our results show that the structural K form or lattice K form, which is found in K feldspars, mica and in other K bearing minerals, released a substantial amount of K which contributed most of the K required during 20 growing cycles of sorghum and wheat. Overall, however, this release still fell short in

meeting the entire crop K needs. In plots receiving the treatment N₁₂₀P_{26.2}K₀, as much as 2,404 kg K ha⁻¹ was released from the structural form of soil K which contributed 77.25 percent K to the total K removed by growing sorghum and wheat over 20 cycles (Table 5 and Fig. 3). Similarly in plots in which sorghum and wheat was grown with the

treatment N₂₄₀P_{52.3}K₀, 1,457 kg K ha⁻¹ was released from this form which contributed 63.8 percent K.

The rate of K release from the structural form decreased significantly with K fertilizer application, consequently, K contribution of this form decreased (Table 5). The most important factor that controls the rate of K release from

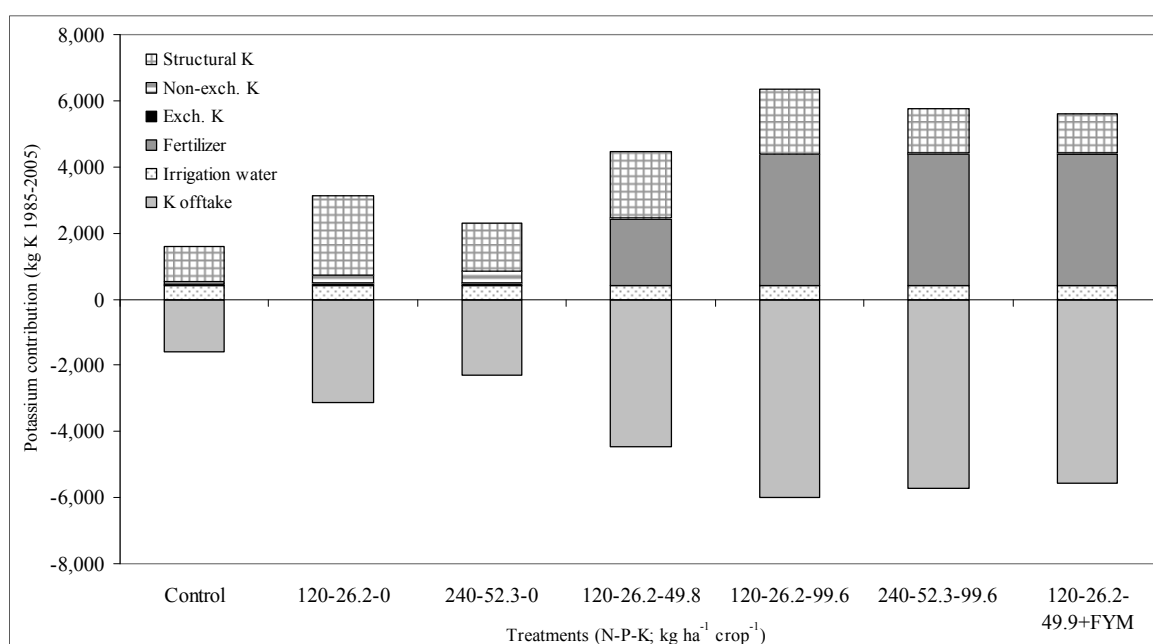


Fig. 3. Total inputs and outputs of K in wheat-sorghum cropping system during 1985-2005.

Research Findings

the structural form is the concentration of K in soil solution. The higher the K concentration in soil solution, the lower the K release from the structural form. Hence, the greater K in soil solution for the K fertilized plots (Table 5) in this long-term experiment must have decreased the release of structural K.

Conclusion

It is concluded that despite substantial K release from the structural form in an Udic Haplustept which contributed 77.3 percent K of the total K removed by sorghum and wheat in a long-term experiment (20 crop cycles), K fertilizer is still needed to maintain K fertility and sustain yields in the cultivation of these crops on this loamy sand soil rich in illite.

These findings refute the general myth that illite dominant alluvial soils of north-western India contain soil reserves of K sufficient to sustain K supply to growing crops over long-periods without any K fertilization. Another, belief that the amount of K in irrigation water in the area is enough to sustain the K requirements of growing

crops has also been shown to be wrong. This long-term study conclusively proved that sufficient K fertilization (at 49.8 kg K ha⁻¹ crop⁻¹) to each crop is needed to sustain optimum crop productivity despite the high contributions from the structural K form. This study also proved that application of high doses of N and P without K (which is a general practice in the area) could be detrimental to both soil and crop productivity on a long-term basis.

Exchangeable and soluble forms of soil K contributed least K to growing sorghum and wheat. The K contribution of non-exchangeable form was found to be much less than that of the structural form of soil K.

References

- Hanway, J.J., and H. Heidel. 1952. Soil analysis methods as used in Iowa State College, Soil Testing Laboratory. Iowa Agriculture, 27:1-13.
- Sekhon, G.S., M.S. Brar, and A. Subba Rao. 1992. Potassium in Some Benchmark Soils of India. PRII, Gurgaon, India.

Singh, K., S.K. Bansal, and Mouinuddin. 2007. Effect of continuous cropping for twenty years on some properties of the intensively cultivated alluvial soils and nutrient indexing of rice. J. Indian Soc. Soil. Sc. 55:265-269.

Sparks, D.L., and P.M. Huang. 1985. Physical Chemistry of soil potassium. In: Munson, R. D (ed.). Potassium in Agriculture. ■

The paper “Potassium Balances and Long-Term Sustainability of Sorghum-Wheat in an Alluvial Soil of Haryana, India” is also available at:

[Regional Activities/India](#)

The Rothamsted Long-Term Experiments: Are They Still of Use?

Jenkinson, D.S. AFRC Inst. of Arable Crops Res. Rothamsted Exp. Stn., Harpenden, Herts AL5 2JQ, England. [Agron J 83:2-10](#). 1991.

The Rothamsted long-term experiments-the Classics-were started almost 150 yr ago. These experiments were originally designed to study the N, P, K, Na, Mg, and Si needs of the field crops then grown in England. This was done by comparing these inorganic nutrients, in various combinations, with farmyard manure, the traditional source of fertility at that time. Although the questions the experiments were originally designed to answer have long been re-solved, the experiments continue to give results of interest to agronomists, ecologists, soil scientists, plant pathologists, and others. The experiments show that grain yields can be sustained (and even increased) for almost 150 years in monocultures of wheat and barley given organic or inorganic fertilizer annually. They provide data on the long-term effects of inorganic fertilizers and organic manures on soil organic matter levels. These data have been used to test computer-based models for the turnover of organic matter in soil. Again, long-term N balances show that there are considerable inputs of N to the soil/plant system, amounting to some 30 kg N ha⁻¹ yr⁻¹ in unfertilized wheat and up to 65 kg ha⁻¹ yr⁻¹ in an arable soil reverting to woodland. These and other results are used to consider the advantages and disadvantages of long-term experiments. Wisely used, long-term experimental sites provide information on the long-term sustainability of agricultural systems that can be obtained in no other way.

Research Findings

Yield Response of Winter Rapeseed to Potassium Fertilization, Use Efficiency and Soil's Potassium Critical Level in the Yangtze River Valley

Zou, J., and J.W. Lu⁽¹⁾.

Abstract

A study on the response of winter rapeseed (*Brassica napus* L.) to potassium (K) application was carried out on soils in the region of the Yangtze River Valley (YRV). Effects of K treatment on K use efficiency by the crop in relation to soil available K levels were also reported. A total of 132 field experiments were conducted in farmers' fields in the major winter rapeseed-growing areas in YRV of China. Results of these field experiments showed that, the average field increment resulting from 100 kg K ha⁻¹ application was 358 kg ha⁻¹, an increase over the control CK (no K) of 18.0 percent in 2005/2006 and 2006/2007. The average internal use efficiency (IE) of K was higher in the CK treatment (21.9 kg grain, kg⁻¹ K uptake) than in the +K (100 kg K ha⁻¹) treatment (17.7 kg grain, kg⁻¹ K uptake). Oilseed rape required 68.1 kg of K to produce 1,000 kg seed. The recovery efficiency of K fertilizer in rapeseed production ranged from 0 to 100 percent, with an average of 39.3

Keywords: Rapeseed (*Brassica napus* L.); Potassium fertilizer; Potassium use efficiency; yield; Soil available K critical level.
Abbreviations: K, potassium; YRV, the Yangtze River Valley; PFP_K, K partial factor productivity; AE_K, K agronomic efficiency; IE_K, K internal efficiency; RIE_K, reciprocal internal efficiency; RE_K, apparent K recovery efficiency; KHI, K harvest index; DM, above-ground plant dry matter.

⁽¹⁾College of Resources and Environment, Huazhong Agricultural University, Wuhan 430070, China. Correspondence author. E-mail address: lujianwei@mail.hzau.edu.cn

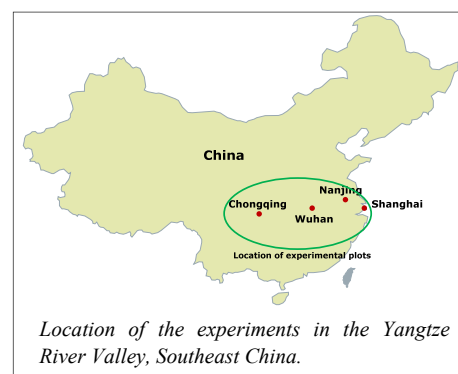
percent. The K balance at most experimental sites was negative, with an average net removal of 117.6 kg K ha⁻¹ in the CK treatment, and 56.8 kg K ha⁻¹ in the +K treatment. The results indicate that there was a significant negative relationship between yield increments by K application and soil available K content. Based on the relative yield of CK/+K at 90 percent level, the soil available K (NH₄OAc-extractable K) critical level was 135 mg kg⁻¹.

Introduction

Winter rapeseed (*Brassica napus* L.) is the dominant oilseed crop in China. The Yangtze River Valley (YRV) is one of the three major rapeseed growing areas in the world and also offers considerable potential of increased production. The planted area of rapeseed in YRV is generally around 6.0×10⁶ ha which is equivalent to 80 percent of the total cultivated rapeseed in China and 20 percent of that of the world (NBSC, 2007; Fu *et al.*, 2003). In addition, Hubei Province has the largest rapeseed production in China both in terms of area cultivated and yield.

Since the 1960s, potassium deficiency has increased over a wide area of China (Lu, 1989; Zhang *et al.*, 2008) and crop demands can no longer be met by the application of manures. Increased crop production from a rise in nitrogen and phosphorus fertilizer use has led to higher depletion of soil potassium. Significant responses to K fertilizer have been demonstrated on a variety of crops (Zhang *et al.*, 2008). Soil potassium deficiency is more serious in southern China, the areas of potassium shortage in the south of the Yangtze River accounting for about 80 percent of that across the entire country (Chen *et al.*, 2008). Soil potassium deficiency is recognized as one of the limiting factors for crop production (including rapeseed) in YRV.

Rapeseed has a high potassium demand to produce a healthy high-yielding crop



containing between 150 to 300 kg of K ha⁻¹ at maximum, excluding roots (Holmes, 1980). Considerable rapeseed yield increases, due to potassium fertilization, have been reported in various countries including Germany (Orlovius, 2000), south-western Australia (Brennan *et al.*, 2007), and Pakistan (Khan, 2004). In China similar increases have been reported by Liu and Tu (1989) and Lu *et al.* (2003). Measurements of extractable soil K have been related to yield responses and K fertilization as observed by Soper (1971). In the USA, 150 mg kg⁻¹ soil of NH₄OAc-extractable K has been recommended as an adequate status (Gerwing *et al.*, 2001) which is similar to that in the UK (MAFF, 2000). These recommendations are in accord with the report of Govahi (2006) stating that rapeseed yield did not respond to applied K fertilizer when 209 mg kg⁻¹ of NH₄OAc-extractable K was present in the soil. Likewise in south-western Australia, rapeseed yields were increased by application of K fertilizer to soils with less than 60 mg kg⁻¹ Colwell-K (Brennan and Bolland, 2006). In China, according to field experiments in the 1980s, a K supply in the soil of 110 mg kg⁻¹ NH₄OAc-extractable K was necessary to obtain maximum yields (Liu and Tu, 1989). However, because of the variance of soil testing methods, soil texture, climate, rapeseed varieties, yield levels, and other cultural management practices, the critical level for soil available K differed between regions.

Research Findings

With the development of crop breeding technology and improvement in farming practices, the main commercial rapeseed cultivars have changed greatly and grain yield levels have increased significantly from the 1980s (Fu *et al.*, 2003). It is widely recognized that information about crop response to fertilization, as well as nutrient use efficiency, soil nutrient balance and soil test requires updating and revaluation (Peck and Soltanpour, 1990; Chen and Zhang, 2006). Unfortunately, there has been little current national or regional emphasis on the effect of K fertilization, soil K balance or K critical level in winter rapeseed-growing in China.

In this paper, we present the results of some recent research on the effect of K fertilizer application on rapeseed in 10 provinces along YRV. The objectives of this work were to assess rapeseed yield response to K fertilizer in this region and to evaluate potassium use efficiency and the K balance of rapeseed systems. Other objectives were to examine the relationship between soil available potassium concentration and yield response to K fertilization, and to revise and update the critical soil available K level for current winter rapeseed production.

Table 1. Experimental sites.

Year	Number of trials	Sites
2000/2001	68	Qichun, county in Hubei province
2004/2005	7	Qichun, county in Hubei province
2005/2006	30	Qichun, Ezhou, Huangmei, Jingmen, Jingzhou, Tianmen, Wuxue, Zhijiang, Xiantao and Honghu counties in Hubei province
2006/2007	27	Pengzhou county in Sichuan, Tongzhou county in Jiangsu, Shanggao county in Jiangxi, Shaoxing county in Zhejiang, Tongnan county in Chongqing, Guangde county in Anhui, Zhijin county in Guizhou, Xinyang county in Henan and Lilin county in Hunan province

Materials and methods

Description of experimental sites

132 field experiments were conducted in farmers' fields in the major winter rapeseed-growing areas of China in 2000/2001 and 2004/2005-2006/2007. The experimental sites were located in 10 provinces of YRV: Hubei, Sichuan, Jiangsu, Jiangxi, Zhejiang, Chongqing, Anhui, Guizhou, Henan and Hunan.

The experimental year, the number of sites and their various locations are listed in Table 1. There were 68 experiments sites in 2000/2001, 7 sites in 2004/2005, 30 sites in 2005/2006, and 27 sites in 2006/2007. In 2005/2006 and 2006/2007, 3 experiments were conducted at each site, each experiment lasting for one year only. The recommended double-low rapeseed (*Brassica napus* L. with low

glucosinolate and erucic acid content) cultivar for each region was used (as listed in the Ministry of Agriculture of the People's Republic of China from 2000 to 2006). The variety of winter rapeseed grown differed between sites. Rice or cotton was grown as a preceding crop.

Soil samples were taken prior to transplanting. The various soil chemical parameters and their ranges, with average values shown in parentheses, were as follows: initial soil pH of all experimental sites ranged from 4.6 to 8.0 (6.5), organic matter from 10.7 to 40.8 g kg⁻¹ (25.3 g kg⁻¹), total N from 0.4 to 2.7 g kg⁻¹ (1.4 g kg⁻¹), available P from 2.1 to 39.3 mg kg⁻¹ (15.5 mg kg⁻¹), available B from 0.15 to 1.36 mg kg⁻¹ (0.34 mg kg⁻¹), and available K from 28.5 to 289.0 mg kg⁻¹ (96.8 mg kg⁻¹).

Experimental design and treatments

Each experiment had two fertilizer treatments (1) CK, 0 kg K ha⁻¹; (2) +K, 100 kg K ha⁻¹ as potassium chloride (60% K₂O) replicated three times using a plot area of 20 m² (4 m×5 m). To ensure that K was the only nutrient element limiting rapeseed production in the control treatment, the following fertilizers were applied to the soil in both treatments: 180 kg N ha⁻¹ as urea (46% N); 39 kg P ha⁻¹ as superphosphate (12% P₂O₅); 7.5 kg borax (11% B) ha⁻¹. Of the nutrients supplied, 60% N, 100% P, 62.5% K and 100% B were applied as basal fertilizers before transplanting. 20% N and 20% K were applied to the soil surface 50-60



Experimental plot of K fertilization in rape seed crop. Photo by Lu Jian-wei.

Research Findings

days after transplanting, and the remainders (20% N and 17.5% K) were applied at stem elongation. Other than fertilizer application and grain harvest, each experimental field was managed using the individual farmer's current management practices.

Plant and soil sampling and analysis

Standard methods of soil analysis were used on sieved air-dried topsoil (0-20 cm) collected before transplanting: soil pH (glass electrode, soil/water ratio of 1:2.5); organic matter (dichromate wet combustion); total N (Kjeldahl digestion with $\text{H}_2\text{SO}_4\text{-K}_2\text{SO}_4\text{-CuSO}_4\text{-Se}$); available P, spectrophotometrically following Olsen extraction with 0.5 M NaHCO_3 at pH 8.5; available K, flame photometry following extraction with 1 M NH_4OAc ; available B was determined by the hot water extraction method (Bao, 2000).

At final harvest (usually in early May), six plants were taken at random from each plot including all above-ground biomass (phytomass). After air-drying for two weeks, all plant samples were separated into seed, pod and stem. Dry weights of each component were determined after oven-drying at 70°C for 48 h. and samples were digested in a double-acid mixture of H_2SO_4 and HClO_4 in the ratio of 95:5. K concentration in the digest was measured by a flame photometer (Bao, 2000). Seed yield was determined from the total plot area (20 m²) at maturity and adjusted to a moisture content of 8.5 percent fresh weight. Pod yield was calculated by the ratio of pod : seed of sampled plant. The same calculation using stem : seed ratio was made to determine stem yield.

Data analysis

Potassium use efficiencies were calculated based on the concepts and terminology of Witt *et al.* (1999), Peng *et al.* (2006) and Dobermann *et al.*

(1996) from their work on irrigated rice. This terminology is as follows:

- **Partial factor productivity** (PFP_K , kg kg^{-1}) = seed yield/K supply.
- **Agronomic K efficiency** (AE_K , kg kg^{-1}) = (seed yield_{+K} – seed yield_{CK})/K supply. This is the incremental efficiency from applied potassium over the control.
- **Internal K efficiency** (IE_K , kg kg^{-1}) = seed yield/K uptake in above-ground plant DM. IE_K is thus defined as the amount of seed yield in kg ha^{-1} produced per kg plant K accumulation in above-ground plant dry matter (DM).
- **Reciprocal internal K efficiency** (RIE_K , kg 1,000 kg^{-1}) = (K uptake in above-ground plant DM/seed yield) $\times 1000$.
- **Apparent K recovery efficiency** (RE_K , %) = (K uptake in above-ground plant DM_{+K} – K uptake in above-ground plant DM_{CK})/K supply $\times 100$.
- **K harvest index** (KHI , kg kg^{-1}) = K uptake in seed/K uptake in above-ground plant DM.

The critical level of soil available K was determined from the relationship between relative yield and the concentration of soil available K (Soper, 1971). Relative yield was determined by dividing the yield observed in the control by the yield of the fertilized treatment. In this research, relative yield was set at 90 percent, and then the critical level of soil available K was determined by the graphic method (Cate and Nelson, 1971) and logarithmic function method (Chen and Zhang, 2006).

Statistical analysis was performed using the data processing system (DPS) software (Tang and Feng, 2002) and SPSS 17.0. The difference between different treatments was determined using the least significant difference (LSD) test at the 0.05 probability level.



Land of rape seed. The experiment setup in one of the regions. Photo by Lu Jian-wei.

Results

Yield response to applied K

The results of field experiments in 2005/2006 and 2006/2007 were used to describe grain yield response to applied K. Grain yield ranged from 956 kg ha^{-1} to 4,087 kg ha^{-1} (mean value 2,206 kg ha^{-1}) for the CK treatments, compared with 1,222 kg ha^{-1} to 4732 kg ha^{-1} (mean value 2,564 kg ha^{-1}) when 100 kg K ha^{-1} was applied (Table 2). K fertilizer application was thus shown to have a positive effect on grain yield in most trials, with increases from 3 kg ha^{-1} to 1,005 kg ha^{-1} (mean value 358 kg ha^{-1}), and an average increased rate of 18 percent.

Fig. 1 describes the relationship between soil K available content (x) and yield response (y_l) in the experimental plots. The equation was $y_l = -374.67 \ln(x) + 1,933.1$ ($r=0.6653^{**}$; $n=57$). The high variability of grain yield in response to applied K between experimental sites probably relates to site differences in soil K status at transplanting and differences in environmental conditions during growth. For example, the available K was only 42.3 mg kg^{-1} at Hubei Ezhou, and the +K treatment increased yield by about 42.5 percent compared with the CK treatment. By contrast, at Hubei Honghu, Jiangxi Shanggao and Zhejiang Shaoxing, where the soil available K was much higher, the increasing rate raised yields by only less than 10 percent.

Differences in grain yield between the various sites were apparent. Jiangsu

Research Findings

Table 2. Soil available K content, rapeseed yield to K fertilizer application, K partial factor productivity (PFP_K) and agronomic efficiency (AE_K) in 2005/2006 and 2006/2007 growing seasons.

	Soil avail. K <i>mg kg⁻¹</i>	Seed Yield		Response to K		AE _K <i>kg kg⁻¹</i>	PFP _K <i>kg kg⁻¹</i>	PFP _N	
		CK	+K					CK	+K
		<i>-----kg ha⁻¹-----</i>		<i>kg ha⁻¹</i>	<i>%</i>			<i>kg kg⁻¹ N</i>	
Range	32.3-289.0	956-4,087	1,222-4,732	184-1,005	-8.2-68.5	0-10.1	12.2-47.3	5.3-22.7	6.8-26.3
Aver.±Std.	115.4±63.8	2,206±603 b	2,564±633 a	358±274	18.0±15.3	3.6±2.7	25.6±3	12.3±3.4 b	14.2±3.5 a

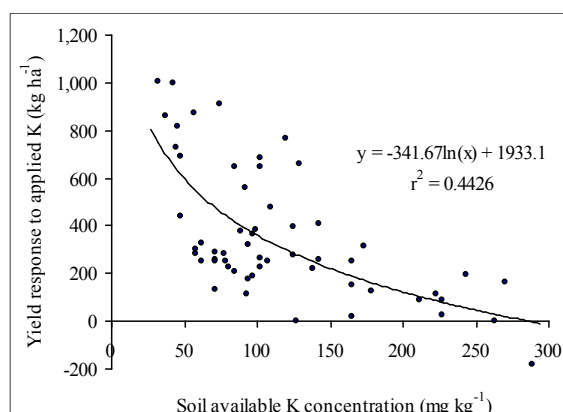


Fig. 1. Relationship between grain yield to applied K and soil available K level.

Tongzhou had a higher grain yield (3,310 kg ha⁻¹ in the CK treatment and 3,825 kg ha⁻¹ in the +K treatment) than the other sites in both CK and +K treatments. The greater yield in Jiangsu was probably due to the higher climatic yield potential caused by lower air temperature and/or higher solar radiation compared with the other sites (Peng *et al.*, 2006). Our data support the results of the National Bureau of Statistics of China (NBSC, 2006) that indicate the unit yield of Jiangsu province was the highest in China. K

partial factor productivity (PFP_K) ranged from 12.2 kg to 47.3 kg (mean value 25.6 kg) grain per kg K applied. Agronomic K efficiency (AE_K) ranged from 0 kg to 10.1 kg (mean value 3.6 kg) grain per kg K applied. Of the 19 sites, Jiangsu Tongzhou and Hubei Ezhou were the highest in PFP_K and AE_K respectively.

Besides PFP_K, Table 2 also gives PFP_N in the CK and +K treatments. PFP_N ranged from 5.3 to 22.7 kg kg⁻¹ N (mean value 12.3 kg kg⁻¹ N) for the CK treatments, compared with 6.8 to 26.3 kg kg⁻¹ N (mean value 14.2 kg kg⁻¹ N) for the +K treatments, findings which indicate that K fertilizer application increased N use efficiency.

Potassium concentration, uptake and nutrient use efficiency

Potassium concentration and accumulation in rapeseed plants for

2005/2006 and 2006/2007 growing seasons are presented in Fig. 2 and 3. Differences in K nutrition status, as expressed in the average values, were clearly reflected by the K concentrations in the stem and pod, which were much higher in the +K treatment (Fig. 1). By contrast, however, K concentrations in the grain were similar in both fertilizer treatments (0.81% in the CK and 0.82% in the +K). This is in agreement with the work of Holmes and Brennan (1980 and 2006), who reported that applications of K fertilizer had a negligible effect on the K concentration in rapeseed grain. The lack of uniformity of K concentration in rapeseed at different experimental sites may be due to the difference in rapeseed varieties.

The total above-ground K accumulation for the CK treatment averaged 117.6 kg K ha⁻¹, while for plants grown in the +K treatment, the average was 156.8 kg K ha⁻¹ (Fig. 2). The result showed that application of K fertilizer could enhance plant uptake by 33.2 percent for K, mostly in the stem.

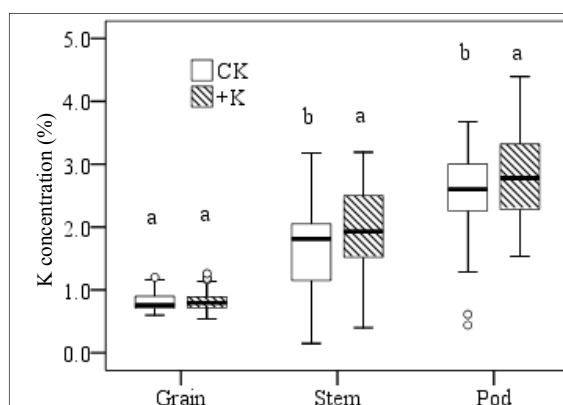


Fig. 2. K concentrations in grain stem and pod.

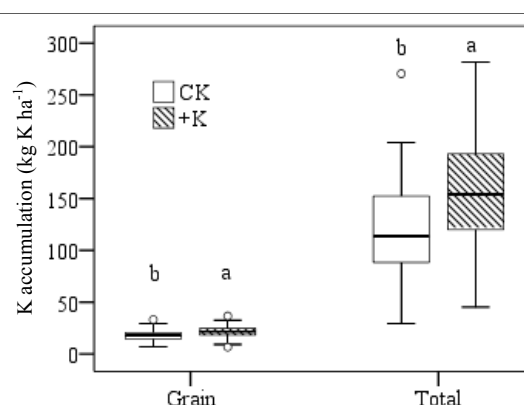


Fig. 3. K accumulations in grain and above-ground plant DM.

Note: The upper and lower limits of each box represent the 25th and 75th percentiles for rapeseed yield. The horizontal line in the center of the box indicates the median. Different lowercase letters (a, b) indicate significant difference ($P < 0.05$).

The nutrient harvest index, i.e. nutrient accumulation in grain as a proportion of nutrient accumulation in above-ground plant DM, was calculated to analyze nutrient distribution in the crop. It is an indicator of the

Research Findings

efficiency with which the plant utilizes mineral nutrients in terms of grain yield production. Potassium harvest index (KHI) in the +K treatment averaged 0.14 kg kg^{-1} , compared to 0.17 kg kg^{-1} in the CK treatment (Table 3). K application caused a decline in KHI except at Jiangsu site. At Anhui Guangde, for example, ample K supply decreased KHI by about 71.6 percent compared to CK plots. These results showed that potassium deficiency may increase the ratio of K accumulation in grain, and a higher ratio of K accumulation occurred in stem and pod when K fertilizer was applied. The findings are in accord with the conclusions of Zou *et al.* (2008) that high yield in rapeseed is closely associated with adequate translocation of potassium to stem and pod.

Internal K efficiency (IE) is the grain yield produced per unit plant nutrient. Nutrient interactions seem to be major determinants of IE. With a limited K supply, there is maximum dilution of K in the plant, and uptake is not restricted by other growth factors such as N or P (Dobermann *et al.*, 1996). Taking all the trials into account, the average IE_K for CK plots was $21.9 \text{ kg grain per kg plant K}$; this was equivalent to $45.7 \text{ kg K per 1,000 kg grain}$. However, when the supply of K is ample and growth is not limited by uptake, maximum K accumulation occurs in the plant (Janssen *et al.*, 1990). The average IE_K was thus much lower in the +K treatment ($17.7 \text{ kg grain per kg plant K}$) than in the CK treatment which was equivalent to $56.5 \text{ kg K per 1,000 kg grain}$.

Apparent potassium recovery efficiency and K balance

Apparent K recovery efficiency (RE_K) is also presented in Table 3. The recovery of K fertilizer was influenced by the soil available K. This agrees with results from Xie (2000), who reported that RE_K for rice was negatively related to the supply of soil potassium at the

same rate of K fertilizer application. Where the soil available K was much lower, for instance, at Hubei Ezhou, Hubei Qichun and Hunan Lilin, RE_K was more than 50 percent.

RE_K was highest (73.6 percent) at Hubei Ezhou and lowest (10.7 percent) at Jiangsu Tongzhou, the average for all sites being 39.3 percent. This result was within the current level of RE_K in China (35 - 50 percent) (Xie *et al.*, 2000; Yan *et al.*, 2008).

Apparent K balance was measured as the difference between total K added and that removed by the crop (Singh *et al.*, 2002). Although K inputs from rainfall and seepage or sedimentation were not measured at the experimental sites, we suspect that these factors had only negligible effects on the K balance (Dobermann *et al.*, 1996). In addition, straw is generally completely removed in most winter rapeseed-growing regions of China. We therefore calculated the apparent K balance based on fertilizer input and above-ground uptake (Table 3). The soil potassium exhaustion was stronger in the CK treatment which ranged from 29.3 to $270.5 \text{ kg K ha}^{-1}$ (mean value $117.6 \text{ kg K ha}^{-1}$) than that in the +K treatment (mean value $56.8 \text{ kg K ha}^{-1}$).

Relationship between soil available K and response of rapeseed to K application

Relative rapeseed yields of CK/+K for all the samples were positively correlated with soil available K as determined by soil extraction with ammonium acetate. As shown in Fig. 4, the soil available K data conformed to an asymptotic relationship with relative yield as interpreted using the logarithmic equation and Cate-Nelson model. The

Table 3. K harvest index (KHI), K internal efficiency (IE_K), reciprocal IE (RIE_K , kg K in above-ground plant DM per 1,000 kg rapeseed), apparent K balance (the rate of K supply - K uptake in above-ground plant DM) and apparent K recovery efficiency (RE_K) in 2005/2006 and 2006/2007 growing seasons.

Treatment		KHI	IE_K	RIE_K	K balance	RE_K
		kg kg^{-1}	kg kg^{-1}	kg 1,000 kg^{-1}	kg K ha^{-1}	%
CK	Range	0.07-0.51	9.1-70.0	14.3-110.2	-270.5 - -29.3	—
	Aver. \pm Std.	0.17 ± 0.07 a	21.9 ± 10.4 a	45.7	-117.6 ± 51.0 b	—
+K	Range	0.06-0.24	9.8-33.1	30.2-102.2	-181.4-54.9	0-100.0
	Aver. \pm Std.	0.14 ± 0.04 b	17.7 ± 5.5 b	56.5	-56.8 ± 53.5 a	39.3 ± 27.1

equation for describing the relationship between relative rapeseed yield (y_2) and soil available K content (x) was $y_2 = 18.176 \ln(x) + 0.7444$ ($r=0.6583^{**}$; $n=132$). It was concluded that the ability of soils to supply K to plants and response of rapeseed yield to K fertilizer application was reflected by soil available K content.

Based on the relative yield of CK/+K at 90 percent level, the soil available K critical level was obtained by the graphical method and logarithmic function method (Cate and Nelson, 1971; Chen and Zhang, 2006). The results showed that the soil K critical level for rapeseed in YRV was 135 mg K kg^{-1} which was identical for the two methods. Using the soil test level of 135 mg K kg^{-1} , 106 experimental fields were below the borderline. In other words, about 80 percent of rapeseed-planting fields in YRV were deficient in potassium.

Discussion

Changes in winter rapeseed response to K fertilization

Rapeseed yield responses to applied K fertilizer in early 1980s were reported by Liu and Tu (1989) in Hubei province. By measuring grain yield responses to K fertilizer applied at 40 experimental sites in 1980s, they observed that rapeseed yield increased significantly by K application, the average increment being 258 kg ha^{-1} , an increasing rate of 14.2 percent and AE_K of $2.0 \text{ kg grain per kg K}$. Our study confirmed this significant

Research Findings

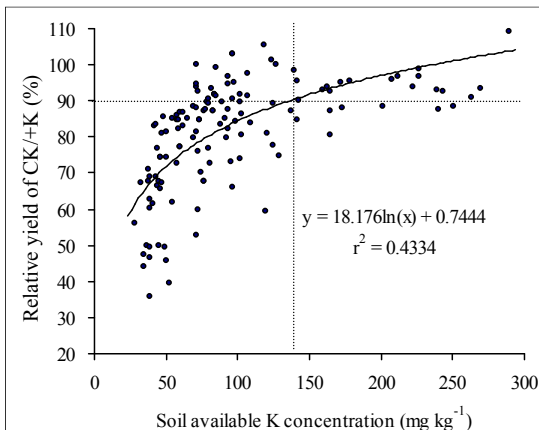


Fig. 4. Determination of soil available K critical level. Relationship between relative rapeseed yield and soil available K level.

increase of rapeseed yield with K fertilization in the other 9 provinces besides Hubei. In 2005/2006 and 2006/2007 growing seasons, the average increment, the percentage increase and AE_K were 358 kg ha^{-1} , 18.0 percent and $3.6 \text{ kg grain kg}^{-1} \text{ K}$, respectively. Compared with grain yield responses to K in the early 1980s, current responses may also be explained by two reasons:

1. The first is that the commercial cultivars of rapeseed grown in YRV have changed from those of the 1980s. The double high (high erucic acid and high glucosinolates) cultivars of the 1980s have been replaced by double low (low erucic acid and low glucosinolates) cultivars (Fu *et al.*, 2003) which according to the findings of Zou *et al.* (2008) have a much higher requirement for K at the current yield level.
2. The second reason is the lower soil potassium status of the rapeseed-planting region of YRV since the 1980s (Xie *et al.*, 2000; Zhang *et al.*, 2008). In China, winter rapeseed is usually cultivated in a crop rotation which includes rice or cotton as a previous crop. Rapeseed in rotation with rice accounts for about 70 percent of Chinese rapeseed acreage (Liu, 1990). At present, although potassium fertilizers are applied extensively in areas of YRV (Xie *et al.*, 2000), the

potassium balance is negative in most of the rice growing areas because of low rates of K fertilizer applied by rice farmers in comparison to the high amounts of K removed in the grain and straw (Dobermann *et al.*, 1996 and Zhang *et al.*, 2008). As a result, soil K status decreases annually in most of the rapeseed growing areas.

Low apparent K recovery versus high soil K exhaustion

China's consumption of K fertilizers has increased steadily from $3.90 \times 10^5 \text{ t K}_2\text{O}$ in 1980 to $6.32 \times 10^6 \text{ t}$ in 2004. The N: K_2O ratio in mineral fertilizers consumption is currently 1:0.24 (Jin *et al.*, 2006). Although a recent survey on fertilizer use by 100 rapeseed farmers in Hubei province showed a somewhat higher ratio of N: K_2O was 1:0.31 (Zou *et al.*, 2008), this is well below the recommended ratio of N: K_2O of 1:0.4-0.7 for current rapeseed production (Zhang *et al.*, 2006 and Zou *et al.*, 2008). Imbalanced use of fertilizers not only limits rapeseed yield but also depletes soil nutrients.

The results of our research showed that fertilizer K application at the rate of 100 kg ha^{-1} in the +K treatment was insufficient to match the K removal (Table 3). The K balance on most experimental sites was negative, with an average net removal of $56.8 \text{ kg K ha}^{-1}$ in the +K treatment and $117.6 \text{ kg K ha}^{-1}$ in the CK treatment. The average apparent K recovery efficiency was 39.3 percent which was much lower compared with that in the developed countries. Reducing the rate of potassium application could improve apparent K recovery efficiency (Xie, 2000) but by decreasing K application, soil K exhaustion may be exacerbated.

Management practices that not only improve apparent K recovery efficiency but also maintain soil potassium fertility include: returning the straw to field and

using organic manure and fertilizer as nutrient sources for crop production. Data from the northern part of the Central Lithuanian Lowland (Kristaponyte, 2005) showed that the potassium balance in the mineral-organic fertilization systems was positive, and potassium fertilizer compensated 106.7 percent of the uptake by plants, whereas in the solely mineral or organic fertilization systems its balance was negative. Dobermann (1996) also reported that where mineral fertilizers are used and straw is incorporated, reserves of soil K are maintained and may even be increased. Results from the soil and fertilizer professional statistical data in 2000 collected by the National Agro-Technical Extension and Service Center showed that on a national basis, there was $3.99 \times 10^6 \text{ t K}_2\text{O}$ in rice straw (Gao *et al.*, 2002). If pre-rice straw could be effectively used, even reducing the amount of potassium fertilizer would not only satisfy the relatively high K demand of rapeseed but also maintain the soil K fertility.

The new soil K critical level and further studies on K management in rapeseed systems

The purpose of soil test critical levels is to describe soil test results in easily understandable terminology and to simplify the process of making fertilizer recommendations by placing soils in response categories (Dahnke and Olson, 1990). These critical levels can provide and estimate the probability of response to fertilization (Heckman *et al.*, 2006). The new soil available K critical level produced at 90 percent relative yield is 135 mg K kg^{-1} for rapeseed in YRV. Previous research in Hubei province of China (Liu and Tu, 1991) has shown that rapeseed yield does not respond to applied K fertilizer when soil NH_4OAc -extractable K values are more than 110 mg kg^{-1} . Thus, some sites (depending on the past critical level) that would be predicted not to respond, do in fact

Research Findings

show responses to K fertilizer when the new soil test critical level is employed.

The new soil test K critical level can be used to predict yield response to K fertilization in current production levels of rapeseed in YRV. The figures in this study, however, cannot be used for K fertilizer recommendations in winter rapeseed. However, in the near future, ongoing research that includes new field trials with different rates of K fertilizer application are likely to provide useful information so that fertilizer recommendations can be made depending on different K soil test levels and yield goals.

Conclusions

Field experiments in 10 provinces of YRV showed that winter rapeseed yield responded positively to fertilizer K application. The yield increment by K application was negatively related to soil NH_4OAc -extractable K concentration and relative yield of CK/+K was positively correlated with soil K. Based on the relative yield at 90 percent level, the soil available K critical level was 135 mg kg^{-1} . This finding indicates that about 80 percent of rapeseed-growing fields in YRV were deficient in potassium. Results also showed that when 100 kg K ha^{-1} was applied, IE_K was $17.7 \text{ kg grain per plant K}$, which is equivalent to a requirement of 56.5 kg K to produce $1,000 \text{ kg grain}$. Moreover, soil K exhaustion was severe compared to the low apparent K recovery in winter rapeseed system.

Acknowledgements

This study was funded by the National Key Technologies R&D Program in the 11th Five Year Plan of China (2008BADA4B08), Program for New Century Excellent Talents in University of Ministry of Education (NCET-07-0345), and Earmarked Fund for Modern Agro-industry Technology Research System of Ministry of Agriculture

(nycytx-005), cooperation project between China and the International Plant Nutrition Institute (IPNI), and cooperation project between China and the International Potash Institute (IPI).

References

- Bao, S.D. 2000. Soil and Agricultural Chemistry Analysis. China Agricultural Press, Beijing, China (in Chinese).
- Brennan, R.F., and M.D.A. Bolland. 2006. Soil and tissue tests to predict the potassium requirements of canola in south-western Australia. *Aust. J. Exp. Agric.* 46:675-679.
- Brennan, R.F., and M.D.A. Bolland. 2007. Influence of potassium and nitrogen fertilizer on yield, oil and protein concentration of canola (*Brassica napus* L.) grain harvested in south-western Australia. *Aust. J. Exp. Agric.* 47:976-983.
- Cate, R.B., and L.A. Nelson. 1971. A simple statistical procedure for partitioning soil test correlation data into two classes. *Soil Sci. Soc. Am. J.* 35:658-660.
- Chen, F., K.Y. Wan, S.S. Chen, G.S. Zhang, and S.Y. Sha. 2008. Progress in study on soil potassium and application of potassium fertilizer in Southern China. *In: Zhou, J.M., Magen, H., (eds.), Soil potassium dynamic and K fertilizer management. Proceedings of 11th K nutrient symposium of Nanjing Inst. of Soil Sci., CAS, IPI. Hohai University Press, Nanjing, China, p. 99-104 (in Chinese).*
- Chen, X.P., and F.S. Zhang. 2006. Building up index system of soil testing and fertilizer recommendation by 3414 fertilizer experiments. *China Agric. Technology Extension* 22:36-39 (in Chinese).
- Dahnke, W.C., and R.A. Olson. 1990. Soil test correlation, calibration, and recommendation. *In: Westerman, R.L., (ed.), Soil testing and plant analysis. ASA, CSSA, and SSSA, Madison, WI, p. 45-71.*
- Dobermann, A., P.C. Sta Cruz, and K.G. Cassman. 1996. Fertilizer inputs, nutrient balance, and soil nutrient-supplying power in intensive, irrigated rice systems. I. Potassium uptake and K balance. *Nutr. Cycl. Agroecosyst.* 46:1-10.
- Fu, T.D., G.S. Yang, J.X. Tu, and C.Z. Ma. 2003. The present and future of rapeseed production in China. *Chin. Oil.* 28(1):11-13.
- Gao, X.Z., W.Q. Ma, C.B. Ma, F.S. Zhang, and Y.H. Wang. 2002. Analysis on the current status of utilization of crop straw in China. *J. Huazhong Agric. Univ.* 21(3):242-247 (in Chinese).
- Gerwing, J., R.H. Gelderman, and A. Bly. 2001. Investigating potassium deficiencies in corn. *Better Crops.* 85:12-13.
- Govahi, M., and M. Saffari. 2006. Effect of potassium and sulphur fertilizers on yield, yield components and seed quality of spring canola (*Brassica napus* L.) seed. *Agron. J.* 5:577-582.
- Heckman, J.R., W. Jokela, T. Morris, D.B. Beegle, J.T. Sims, F.J. Coale, S. Herbert, T. Griffin, B. Hoskins, J. Jemison, W.M. Sullivan, D. Bhumbla, G. Estes, and W.S. Reid. 2006. Soil test calibration for predicting corn response to phosphorus in the northeast USA. *Agron. J.* 98:280-288.
- Hergert, G.W., W.L. Pan, J.H. Huggins, Grove, and T.R. Peck. 1997. Adequacy of current fertilizer recommendations for site-specific management. *In: Pierce, F.J., Sadler, E.J., (eds.), The state of site-specific management for agriculture. ASA, Madison, WI, p. 293-300.*
- Holmes, M.R.J. 1980. Nutrition of the oilseed rape crop. Applied science publishers LTD London.

Research Findings

- Janssen, B.H., F.C.T. Guiking, D. van der Eijk, E.M.A. Smaling, J. Wolf, H. van Reuler. 1990. A system for quantitative evaluation of the fertility of tropical soils (QUEFTS). *Geoderma* 46:299-318.
- Jin, J.Y., J.K. Li, S.T. Li. 2006. Chemical fertilizer and food security-the demand of chemical fertilizer for cereal crops. *Phos. Comp. Fert.* 21(3):1-6 (in Chinese).
- Khan, H.Z., M.A. Malik, M.F. Saleem, and I. Aziz. 2004. Effect of different potassium fertilization levels on growth, seed yield and oil contents of canola (*Brassica napus* L.). *Int. J. Agric. Biol.* 6:557-559.
- Kristaponyte, I. 2005. Effect of fertilization systems on the balance of plant nutrients and soil agrochemical properties. *Agron. J.* 3(1):45-54.
- Liu, C.Z., and Y.C. Tu. 1989. Study on combined application of nitrogen, phosphorus and potassium to rapeseed. In: *Soil and Fertilizer Institute of Chinese Academy of Agriculture Science*, (ed.), Symposium of National Colloquium of Balanced Fertilizer. Agricultural Press, Beijing, China, p. 215-220 (in Chinese).
- Liu, H.L. 1987. Practical cultivation of rapeseed. Scientific Technique Press, Shanghai, China, p. 67-69 (in Chinese).
- Lu, J.W., F. Chen, C.B. Yu, J.F. Li, Z.Q. Zhang, D.B. Liu, and T. Xiong. 2003. Response of rapeseed yield to K application and primary study of soil critical available K content for rapeseed. *Chin. J. Oil Crop Sci.* 25(4):107-112 (in Chinese).
- Lu, R.K. 1989. General status of nutrients (N, P, K) in soils of China. *Acta Pedol. Sin.* 26(3):280-286 (in Chinese).
- MAFF (UK-Ministry of Agriculture, Fisheries and Food). 2000. Fertiliser Recommendations for agricultural and horticultural crops (RB 209), 7th ed. The Stationery Office, Norwich.
- NBSC (The National Bureau of Statistics of China). 2007. Chinese Statistical Yearbook. <http://www.stats.gov.cn/tjsj/ndsj/2007/indexch.htm> (in Chinese).
- Orlovius, K. 2000. Results of potash, magnesium and sulphur fertilizing experiments on oil crops in Germany. In: *Zbilansowanie nawozenie rzepaku. Aktualne problemy*, p. 229-239, IPI/IMPHOS, Poznan.
- Peck, T.R., and R.N. Soltanpour. 1990. The principles of soil testing. In: Westerman, R.L., (ed.), *Soil testing and plant analysis*. ASA, CSSA, and SSSA, Madison, WI, p. 1-9.
- Peng, S., R.J. Buresh, J. Huang, J. Yang, Y. Zou, X. Zhong, G. Wang, and F. Zhang. 2006. Strategies for overcoming low agronomic nitrogen use efficiency in irrigated rice systems in China. *Field Crops Res.* 96:37-47.
- Singh, M., V.P. Singh, and D.D. Reddy. 2002. Potassium balance and release kinetics under continuous rice-wheat cropping system in Vertisol. *Field Crops Res.* 77:81-91.
- Soper, R.J. 1971. Soil tests as a means of predicting response of rape to added N, P and K. *Agron. J.* 63:564-566.
- Tang, Q.Y., and M.G. Feng. 2002. DPS Data Processing System for Practical Statistics. Science Press, Beijing, China, p. 648, <http://www.chinadps.net> (in Chinese).
- Witt, C., A. Dobermann, S. Abdulrachman, H.C. Gines, G.H. Wang, R. Nagarajan, S. Satawatananon, T.T. Son, P.S. Tan, L.V. Tiem, G.C. Simbahan, and D.C. Olk. 1999. Internal nutrient efficiencies of irrigated lowland rice in tropical and subtropical Asia. *Field Crops Res.* 63:113-138.
- Xie, J.C., and J.M. Zhou. 1999. Progress in study on soil potassium and application of potassium in China. *Soils.* 31(5):244-254 (in Chinese).
- Xie, J.C., J.M. Zhou, and R. Härdter. 2000. Potassium in Chinese agriculture. Hohai University Press, Nanjing, China (in Chinese).
- Yan, X., J.Y. Jin, P. He, and M.Z. Liang. 2008. Recent advances in Technology of increasing fertilizer use efficiency. *Sci. Agric. Sin.*, 41(2):450-459 (in Chinese).
- Zhang, F.S., X.P. Chen, L.L. Cheng, and W.F. Zhang. 2008. Soil potassium balance and K fertilizer requirement in China. In: Zhou, J.M., Magen, H., (eds.), *Soil potassium dynamic and K fertilizer management*. Proceedings of 11th K nutrient symposium of Nanjing Inst. of Soil Sci., CAS, IPI. Hohai University Press, Nanjing, China, p. 251-257 (in Chinese).
- Zou, J., J.W. Lu, F. Chen, and M.X. Lu. 2008. Effect of potassium fertilization on rapeseed and potassium application technique in China. In: Zhou, J.M., Magen, H., (eds.), *Soil potassium dynamic and K fertilizer management*. Proceedings of 11th K nutrient symposium of Nanjing Inst. of Soil Sci., CAS, IPI. Hohai University Press, Nanjing, China, p. 289-297 (in Chinese).
- Zou, J., J.W. Lu, R.L. Liu, Z.Y. Zheng, W.X. Li, and Z.P. Jiang. 2008. Dynamics of dry mass accumulation and nutrients uptake in 4 double-low rapeseed (*Brassica napus* L.) varieties. *J. Huazhong Agric. Univ.* 27(2):229-234 (in Chinese). ■

The paper “Yield Response of Winter Rapeseed to Potassium Fertilization, Use Efficiency and Soil’s Potassium Critical Level in the Yangtze River Valley” appears also at:

[Regional Activities/China](#)

IPI Events

July 2009

IPI-Corvinus University Budapest International Symposium on “Nutrient Management and Nutrient Demand of Energy Plants”, 6-9 July 2009, Budapest, Hungary.

Terbe, I.⁽¹⁾, N. Kappel⁽¹⁾, and T. Popp⁽²⁾.

The European Environmental Agency (EEA) reported that in 2009-2010 bio-energy provides about 10-12 percent of the total energy demand whilst, in 2030, it is estimated that 15-16 percent will be derived from energy plants. Consequently, in Europe including in Eastern Europe, energy plant cultivation is increasingly becoming the focus of researchers and farmers.

Depending on the agro-climatic conditions, different arable and arboreal plant species are used for producing bio-energy. Many conferences and publications discuss the technological facilities and questions of biogas, bioethanol or biodiesel production, as well as the availability of energy plants, but the nutrient demand of energy plants and nutrient management during cultivation receive very little attention. To provide some discussion on these important topics, the International Potash Institute (IPI) and the Corvinus University of Budapest organized an international symposium on “Nutrient management and nutrient demand of energy plants” in July 2009. A number of researcher and professionals from several countries attended the event.

After the official opening – presented by Dr. Tamás Mészáros, Rector from the Corvinus University of Budapest – Dr. Tamás Németh, Secretary from the Hungarian Academy of Science, presented the keynote address on “Fuel and energy from plants – threats or opportunities for the world”. He provided estimations on the role of bio-energy in world’s energy production,

and presented data to highlight the disparity in this field in certain regions of the world.

The symposium presentations were organized in four sessions. The first session dealt with new and traditional crops for bio-energy. Nutrient consumption of some non-traditional energy crops was presented by Prof. Dr. Margarita Nikolova from Bulgaria. From Dr. Victor Bruckman of the Commission for Interdisciplinary Ecological Studies in Austria, delegates heard that a new generation of biofuels has awakened optimism about our ability to reduce dependency on petroleum and contribute to a sustainable and environmentally-friendly future for energy production and utilization.

The second session highlighted the



Participants at the field trip. Photo by Corvinus University.

quality requirement of crops for bio-energy. Prof. Dr. Ismail Cakmak from Sabanci University, Turkey provided a very exciting presentation about the role of mineral nutrition in carbon allocation and biomass production in bio-energy plants. A Hungarian case-study provided valuable information about the mineral nutrition of maize produced for bioethanol. The paper was presented by Dr. Péter Csathó from the Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences. Aida Bani of the Agro-Environmental Department at the Agricultural University of Tirana in Albania, talked about the effects of nutrients on biomass production in



Participants of the symposium at the poster session. Photo by Corvinus University.

hyperaccumulator plants as a potential source of energy.

The third session focused on optimal crop rotation and nutrient balance for bio-energy plants. Nutrient management and the effect of potassium fertilization were discussed. Prof. Dr. Andreas Gransee from K+S KALI GmbH emphasized that the determination of adequate fertilizer supply is a prerequisite for all farming systems. Hungarian researchers studied the effect of increasing potassium mineral fertilizer supply on the yield and quality parameters of five corn hybrids in a field experiment. Experiments were carried out also at the Lithuanian Institute of Agriculture, as presented by Zydre Kadziulienė, to identify changes in the biochemical composition of tall fescue at different nitrogen inputs for biomass cultivation.

In the final session, the energy and CO₂ balance of crops grown for bio-energy was the main topic. Dr. Jürgen Küsters from Yara International ASA reported on energy and CO₂ balances, which are calculated for biofuels (biodiesel and bioethanol), as well as for the incineration of biomass and for the production of biogas. Prof. Éva Salamon-Albert of the Faculty of Sciences at the University of Pécs in Hungary introduced a tall wheat grass cultivar as an alternative energy crop in Hungary.

A one-day excursion programme was also organized to Agrospeciál Kft. in Pálhalma and the town of Szekszárd. In

⁽¹⁾Corvinus University of Budapest, Hungary.

⁽²⁾IPI Coordinator Central Europe.

IPI Events

Pálhalma, a biogas plant was visited, where farmyard manure (slurry) and other organic waste products are being processed. In Szekszárd, Minerág Kft. provided a tour round the experiments at their energy plant plantation. Dr. István Csibör, director of the facility, informed delegates that Szekszárdi Növény ZRt. is one of the most important agricultural enterprises in the region due to their organizational, trading and production activities. The Bényei farm was then visited, where 300 ha plantation of energy crops are grown, including the largest collection of *Populus nigra* clones in Europe and cultivation of mother-plants of *Populus nigra* and *Populus x euramericana*. Finally the programme ended with a wine tasting. The Mészáros Winery and House of Wine provided an ideal place for tasting the typical wines of Hungary made from *merlot*, *cabernet* and *kadarka* varieties.

To access the symposium presentations, click on the IPI website at <http://www.ipipotash.org/speech/index.php?ev=86&o=0>. ■

The report on the IPI-Corvinus University Budapest International Symposium on “Nutrient Management and Nutrient Demand of Energy Plants”, 6-9 July 2009, Budapest, Hungary appears also at

[Regional Activities/Central Europe](#)

February 2010

FAI-IPI 6th Round Table Conference on “Enhancing Nutrient Use Efficiency through Potassium”

A Round Table Conference on “Enhancing Nutrient Use Efficiency through Potassium” on 9th February, 2010 in New Delhi was co-organised by the International Potash Institute (IPI) and The Fertiliser Association of India (FAI).

Thirty scientists and representatives from the Indian Council of Agricultural Research (ICAR), State Agricultural Universities, Planning Commission,



Some participants of the 6th IPI-FAI Round Table on “Enhancing Nutrient Use Efficiency through Potassium”, 9 February 2010 in New Delhi. From left to right: Prof. P.K. Aggrawal, Dr. R.K. Tewatia, Mr. S. Chander, Dr. P.S. Gahlaut, Mr. H. Magen, Dr. M. Assaraf, and Dr. Ch. Srinivasa Rao. Photo by FAI.

Ministry of Agriculture, International Plant Nutrition Institute (IPNI), Potash Research Institute of India (PRII), International Zinc Association (IZA), and the Indian Fertiliser Industry participated in the event. Mr. S. Chander, Director General, FAI, New Delhi welcomed the participants, Mr. H. Magen, Director, IPI, Switzerland gave an introduction to the program, and Dr. P.S. Gahlaut, Managing Director, Indian Potash Limited (IPL), New Delhi delivered the opening remarks.

Mr. Chander highlighted various FAI programs implemented in collaboration with international organizations during recent years. The current FAI-IPI Round Table Conference is one such ongoing program and is the sixth in the series. Earlier Round Table events were organized at Chandigarh, Pune, Chennai, Bhubaneswar and Lucknow.

The need for improving agronomic efficiency of plant nutrients, which was reported to be declining over the years in India, was emphasized by Mr. Magen. There are a number of factors which affect nitrogen use efficiency (NUE). However, he stated that NUE could be increased by 20 per cent by promoting best management practices. He drew delegates' attention to the program of

four specific papers on NUE, stating that they should provide opportunities for discussion on the factors involved in the decrease in agronomic efficiency of plant nutrients in both irrigated and rainfed agricultural systems in India. Hillel expressed a hope that deliberations and discussions would be focused on the objectives of the program and that answers and recommendations on the questions being faced would emerge.

In his opening remarks, Dr. Gahlaut stated that efficient use of fertilizers was of critical importance because raw materials for fertilizers are finite and declining availability is predicted. The situation for potassium is somewhat better. As a group, there should be concern for agricultural sustainability and the welfare of agriculture and farmers. Dr. Gahlaut pointed out that the rising cost of fertilizers was inevitable but fertilizer use by farmers had to be profitable in all cropping systems. Raising concerns about stagnation in agricultural production, he mentioned that enhancing crop productivity was a necessity to meet the food demand for an ever increasing population. He stated that an appropriate benchmark, which was deemed achievable for farmers, should

IPI Events

be fixed. Dr. Gahlaut added that potash (K) has been used in India since before independence. A company called Indian Potash Limited (IPL) was created by the Government of India with a mandate to promote balanced fertilization and to establish potash requirements. He mentioned that thousands of experiments had been conducted to highlight the benefits of potash in improving crop yields and quality. He informed the delegates that potash use has been accepted by farmers but they need continued support with knowledge on nutrient management in various cropping systems and conditions. With enhanced NUE, through potash application and better protection of crops from various plant pests, farmers can save thousands of rupees on pesticides by optimized use of potash. The use of potash will go a long way in improving the environment. He expressed his hope that the Round Table would help in taking the best available knowledge to farmers.

Four papers were presented to the delegates:

1. Yield potential of rice and wheat in Indo-Gangetic plains by Dr. P.K. Aggrawal, National Professor, Indian Agricultural Research Institute (IARI), New Delhi.
2. Analyzing nitrogen use efficiency in long-term experiments in irrigated wheat and rice by Dr. A. Swarup, Head, Division of Soil Science and Agricultural Chemistry, IARI, New Delhi.
3. Analyzing nitrogen use efficiency in long-term experiments in rainfed crops by Dr. Ch. Srinivasa Rao, Principal Scientist, Central Research Institute for Dryland Agriculture (CRIDA) Hyderabad.
4. N & K interaction in potato by Dr. S.P. Trehan, Principal Scientist, Central Potato Research Station (CPRS), Jalandhar.

Each paper was followed by extensive discussion.

In the concluding session, Mr. Chander requested participants to provide their recommendations. Summing up the session, he mentioned that current potash consumption in India was 1 mt less than the requirement for sustainable food production. Use of potash should be promoted where it is currently under-utilized. Consideration for all limiting nutrients is required to achieve optimum yields. He added that integrated nutrient management is essential to improve soil health and crop productivity.

Mr. Magen provided some concluding remarks. He informed delegates that the idea of the Round Table had come out of the IFA agronomic workshop on “Fertiliser Best Management Practices (FBMPs)” held in Brussels, Belgium in March, 2007. In addition, he cited the papers of Dr. P.D. Sharma and Dr. P.P. Biswas on “A New Approach for Estimating Fertilizer Response Ratio - the Indian Scenario” published in the Indian Journal of Fertilizers, and the research of Dr. P.K. Aggrawal, as further sources for preparing this Round Table. Mr. Magen felt that while NUE in irrigated rice and wheat in the Indo-Gangetic Plains can be calculated from experimental results, this information was lacking in rainfed areas, and hence, called for more systematic long-term research in rainfed areas. He observed that the data on recovery efficiency (amounts of nutrients taken by plants) was lacking in the papers presented, and were needed to better understand other aspects of NUE. He also mentioned that Dr. P.K. Aggrawal in his presentation on “Yield Potential of Rice and Wheat in Indo Gangetic Plains” had set the tune excellently and provided a realistic yield target for irrigated rice and wheat production. However, he stated that work on yield potential in rainfed crops was not presented at the meeting, and needs to be further explored. Finally, Mr. Magen requested delegates to take away key messages according to their own area of interest. For example, he stated that key messages for him included the importance of NUE and the

environmental benefits it brings. He thanked all the speakers for their presentations and all the participants for their active participation in the discussion, as did Dr. R.K. Tewatia in the final vote of thanks.

Conclusions and recommendations

Some of the major conclusions and recommendations that emerged from presentations and discussions during the conference are highlighted below:

1. The gap between the average production and attainable yield of rice and wheat is very high in the Indo-Gangetic plain, especially in the eastern region. To bridge the gap, assured availability and application of inputs and their efficient management through educating the farmers are required. Dr. Aggrawal stated that there was a yield gap of approx 2 mt ha⁻¹ between actual and attainable yields. More than half (56%) of this gap could be attained by efficient nutrient management.
2. The results from the long term fertilizer experiments show that Integrated Plant Nutrition Systems (IPNS) is the right approach to improve soil health as well as enhance NUE. Application of FYM at 10-15 mt ha⁻¹ (when available) along with soil test-based NPK application, usually improves sustainable production in different cropping systems and different soil types.
3. The effect of potassium on NUE in irrigated cereal-based systems was well presented by Dr. A. Swarup through meticulous analysis of long-term fertilizer experiments in various parts of India. The agronomic efficiency of nitrogen (AE_n) could be significantly enhanced through the appropriate use of P and K. Addition of P and K over N alone increased AE_n, which varied from 85% in wheat to 67% in summer

IPI Events

rice. Clearly, these long-term experiments provide an excellent tool to diagnose and plan for better nutrient management in cereal-based cropping systems.

4. Potassium plays a key role in balanced fertilization in both rainfed and dryland areas. However, as presented by Dr. Ch. Srinivasarao, the average use of potassium in these areas is rather low as compared to irrigated areas. Considering the role of potassium in alleviation of water stress in plants, it should be promoted in rainfed and dryland areas. The forum also stressed the need to include K treatments in long-term fertilizer experiments being conducted in rainfed/dryland agriculture. The lack of these treatments prevents systematic evaluation as conducted in long-term fertilizer experiments on irrigated land.
5. The positive interaction effect of N x K has been observed in cereals and other crops like potato. This positive interaction effect needs to be optimized through adequate application of K over N application to further improve NUE.
6. Potato cultivars showed wide variation in agronomic use efficiency (AUE) of N and K. The hybrid JX 576 had the highest AUE of N & K among the cultivars tested. It showed about 15-24% greater AUE of N & K than the best control, Kufri Pukhraj. Farmers are to be advised to cultivate suitable varieties to achieve higher NUE.
7. Potassium recommendations need to account for soil type, available K, type of crops and the agro-climatic zone. The integration of all these factors will lead to improved potassium fertilizer recommendations.
8. On the basis of an ideal ratio of nutrient use (4:2:1), which can be used as a general guideline, it is observed that there is gap of about 1

million mt of K between current consumption and that required for adequate food production in India. Therefore, an additional supply of potash fertilizer needs to be provided in the future to enable optimized nutrient management in Indian agriculture. ■

The report on the FAI-IPI 6th Round Table Conference on “Enhancing Nutrient Use Efficiency through Potassium” appears also at

[Regional Activities/India](#)

Europe. The symposium will be announced at all universities in Turkey. Poster presentations are open to all, and students in the region are particularly encouraged to participate and present research related to the themes of the symposium.

For more details see [IPI website](#) or contact IPI Coordinator [Mr. M. Marchand](#). ■

Other Events

November 2010

International symposium on “Soil Management and Potash Fertilizer Uses in West Asia and North Africa Region”, Antalya, Turkey, 22-25 November 2010.

See the [2nd circular](#) on the IPI website.

The International Potash Institute (IPI), in collaboration with Ege University organizes an international symposium in Antalya entitled "Soil Management and Potash Fertilizer Uses in West Asia and North Africa Region". The WANA region is known for its exports of agricultural products, including fruits and vegetables, which provide important incomes. However, a large part of the production is used to feed the population, which is increasing in a huge way. Balanced fertilization and particularly the use of potash is generally not well known.

During the symposium, issues including soil fertility, quality of mineral fertilizers, efficient use of fertilizers, fertigation and foliar application will be discussed. This event will be of interest to soil and plant nutrition scientists, agronomists, and extension officers from universities and research organizations, government offices, agribusinesses and farmers who share an interest in improving food production and quality in the region. The organizers anticipate participation from across the region. Invited speakers will include scientists from the WANA region and from

Autumn 2011

IPI is preparing for an international symposium in South West China, with the tentative title “Potassium in Plant and Soil Systems in China”.

More details will soon be available (see on [IPI website](#)). ■

August 2010

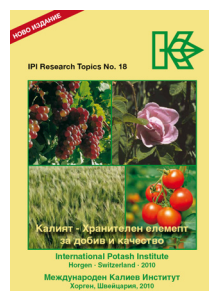
19th World Congress of Soil Science, 1-6 August 2010, Brisbane Convention and Exhibition Centre, Queensland, Australia.

For more details see [congress website](#). ■

November 2010

3rd International Rice Congress, Vietnam National Convention Center, Hanoi, Vietnam, 8-12 November 2010. With the theme “Rice for Future Generations”, IRC 2010 will provide a forum for representatives from the public and private sectors including researchers, scientists, professionals, traders, and policy makers. Delegates will discuss the latest rice research, future technologies, trade issues, and policies that will define the future role of rice in supporting the poor rice-dependent communities. For more details go to <http://www.ricecongress.com/>. ■

New Publications



IPI Research Topics No. 18: Potassium - Decisive Nutrient for Yield and Quality. 2010. Bulgarian. By Nikolova, M. 88 p. ISBN 978-3-

905887-00-6; DOI 10.3235/978-3-905887-00-6. Available on the [IPI website](http://www.ipi.org). For copies, contact [Dr. T. Popp](mailto:Dr.T.Popp@ipi.org). ■



Balanced Fertilization—Potassium Role. 2010. [English](#) and [Oriya](#). Edited by Jena, D., B. Thirugnanasothy, and G.H. Santra. IPI-OUAT publication. Available on the IPI website. For copies contact [Prof. D. Jena](mailto:Prof.D.Jena@ipi.org). ■

Publications by the PDA

The Potash Development Association (PDA) is an independent organisation formed in 1984 to provide technical information and advice in the UK on soil fertility, plant nutrition and fertilizer use with particular emphasis on potash. See also www.pda.org.uk/.

Note: Hardcopies of PDA's publications are available only in the UK and Ireland.



- **Missed applications of potash put arable crops at risk.** March 2010. See [PDA website](http://www.pda.org.uk/). ■

Other Publications



Mobilizing The Potential of Rural and Agricultural Extension. Christoplos, I., Danish Institute for International Studies.

Food and Agriculture Organization of the United Nations (FAO), Office of Knowledge Exchange, Research and Extension, The Global Forum for Rural Advisory Services, Rome, 2010. <http://www.fao.org/docrep/012/i1444e/i1444e00.htm> ■



Strengthening Agricultural Extension and Advisory Systems: Procedures for Assessing, Transforming, and Evaluating Extension

Systems. Swanson, B.E., and R. Rajalahti. 2010. The World Bank, Agriculture and Rural Development. Discussion Paper 45. See PDF at [The Word Bank website](http://www.worldbank.org/po45). ■

in the Literature

Potassium Substitution by Sodium in Sugar Beet (*Beta vulgaris*) Nutrition on K-Fixing Soils. Wakeel, A., D. Steffens, and S. Schubert. 2009. [J. of Plant Nut. and Soil Sci. 173, 1:127-134](#). DOI: 10.1002/jpln.200900270.

Abstract:

Alluvial soils with illite and vermiculite clay minerals are highly potassium (K)-fixing. Such soils have been reported to require a huge amount of K fertilization for optimum plant growth. For halophytic plants such as sugar beet, sodium (Na) can be an alternative to K under such conditions. This study was conducted to investigate the possible substitution of K by Na fertilization with reference to K-fixing soils. Three

soils, *i.e.*, Kleinlinden (subsoil), Giessen (alluvial), and Trebur (alluvial), differing in K-fixing capacities, were selected, and sugar beet plants were grown in Ahr pots with 15 kg soil pot⁻¹. Three treatments (no K and Na, K equal to K-fixing capacity of soil, and Na equivalent to regular K fertilization) were applied. In a second experiment, containers (90 cm × 40 cm × 40 cm) were used with 170 kg Kleinlinden soil each, and one sugar beet plant per container was grown. In both experiments, plants were grown till beet maturity, and beets were analyzed for sucrose concentration and other quality parameters such as α-amino nitrogen to calculate white-sugar yield with the New Brunswick formula. The results showed that growth and quality of sugar beet were not affected by Na application, and ultimately there was no decrease in white-sugar yield. Moreover, the soils with more K-fixing capacity were more suitable for K substitution by Na. It is concluded that Na can substitute K in sugar beet nutrition to a high degree and soils with high K-fixing capacity have more potential for this substitution. ■

Performance of Annual and Perennial Biofuel Crops: Nutrient Removal during the First Two Years. Propheter, J.L., and S. Staggenborg. 2010. [Agron. J. 102, 2:798-805](#).

Abstract:

Nutrient removal is an important factor that must be considered in lignocellulosic fuel production. This study was conducted to determine the macronutrient (N, P, and K) composition of grain and stover, as well as the nutrient removal in grain, stover, and total biomass of annual and perennial C4 crops in northeast Kansas in 2007 and 2008. Crops studied were corn (*Zea mays* L.) grown continuously or rotated with soybean [*Glycine max* (L.) Merr.]; five sorghum [*Sorghum bicolor* (L.) Moench] cultivars, brown

in the Literature

midrib (bmr), photoperiod sensitive, sweet, and two dual-purpose forage cultivars; and three perennial warm-season grasses, switchgrass (*Panicum virgatum* L.), big bluestem (*Andropogon gerardii* Vitman), and Miscanthus (*Miscanthus x giganteus*). Perennial grass yields were from the first two harvests after establishment. Yields and total nutrient removal rates were greater for annual crops than for perennial grasses. Perennial grass nutrient concentrations were greatest in the establishment year (2007). Perennial grass yields increased from 2007 to 2008, but nutrient removal was not affected by the yield increase. Grain nutrient removal rates were greatest for corn even though nutrient concentrations were less than or equal to those for sorghum grain. Total nutrient removal rates were most affected by biomass yield and soil test P levels. Total K removal was greatest for the photoperiod-sensitive, sweet, and dual-purpose forage sorghum cultivars. These results indicate that higher annual crop yields will remove more nutrients than perennial grasses during the grass establishment period. ■

Doses e Formas de Aplicação da Adubação Potássica na Rotação Soja, Milheto e Algodão em Sistema Plantio Direto; Potassium Fertilization of Soybean, Pearl Millet, and Cotton in a No-Till Rotation System in the Cerrado Region. Alberto Carlos de Campos Bernardi, Juarez Patrício de Oliveira Júnior, Wilson Mozena Leandro, Tiago Gomes da Silva Mesquita, Pedro Luiz de Freitas, Maria da Conceição Santana Carvalho. [Pesquisa Agropecuária 39 \(2\):158-167 \(2009\)](#). Portuguese. ISSN 1517-6398 / e-ISSN 1983-4063. This paper is based on a project supported by IPI.

Abstract:

Este estudo teve como objetivo avaliar a eficiência da adubação potássica, com relação às doses, modos (sulco, a lanço

e parcelada) e épocas de aplicação (pré-semeadura, semeadura e cobertura), na sucessão de culturas soja-milheto-algodoeiro, cultivadas em sistema plantio direto, em Latossolo Vermelho, no município de Turvelândia, Goiás (17° 51'S, 50°18'W). O delineamento experimental adotado foi o de blocos casualizados, com quatro repetições, em esquema fatorial. A fonte de potássio utilizada nas adubações foi o cloreto de potássio. Na soja, os tratamentos utilizados foram doses de K₂O (0 kg ha⁻¹, 30 kg ha⁻¹, 60 kg ha⁻¹ e 180 kg ha⁻¹), aplicadas em pré-semeadura (a lanço) e na semeadura (no sulco), com e sem cobertura. Na cultura do algodoeiro, os tratamentos foram doses de K₂O (0 kg ha⁻¹, 60 kg ha⁻¹, 120 kg ha⁻¹ e 240 kg ha⁻¹), aplicadas em pré-semeadura (a lanço) e na semeadura (no sulco), com 0, 1 ou 2 coberturas. A adubação em pré-semeadura foi realizada no milheto. Não houve efeito da adubação potássica sobre a produtividade da cultura da soja. O milheto, como cobertura do solo, aproveitou, mais eficientemente, a dose de 60 kg ha⁻¹ de K₂O, aplicada na cultura da soja. Para a cultura do algodoeiro, a maior eficiência agrônômica foi obtida com dose de 146 kg ha⁻¹ de K₂O, em pré-semeadura. Os resultados indicaram, também, que houve efeito positivo da adubação potássica sobre a qualidade da fibra do algodão.

The main objective of this study was to evaluate the efficiency of potassium fertilizer application, as related to rate, placement (in-row, broadcast, and split topdress) and time (before sowing, at sowing, and topdressing), in a soybean, pearl millet, and cotton no-till rotation system, in a typical dystrophic Red Latosol (Hapludox), in Turvelândia, Goiás State, Brazil (17°51'S, 50°18'W). The experimental design was a factorial randomized block, with 4 replications. Potassium source was KCl. Potassium was applied to soybean (0 kg ha⁻¹, 30 kg ha⁻¹, 60 kg ha⁻¹, and 180 kg ha⁻¹ of K₂O) in the planting row or broadcasted before sowing, at sowing, or topdressed.

For cotton, the K rates were 0 kg ha⁻¹, 60 kg ha⁻¹, 120 kg ha⁻¹, and 240 kg ha⁻¹ of K₂O, applied before sowing and placed in the planting row, with none or one topdressing, or split in two applications. The pre-planting cotton K was applied in the pearl millet. There was no effect of potassium fertilization on soybean yield. As a cover crop, pearl millet used, more efficiently, the 60 kg ha⁻¹ of K₂O rate. Results showed that the best cotton agronomic efficiency was obtained with 146 kg ha⁻¹ of K₂O, supplied before sowing. Results also showed positive effects of potassium fertilization on cotton fiber quality. ■

Read on: Papers and a Book

- **Impact of Genetically Engineered Crops on Farm Sustainability in the United States.** Committee on the Impact of Biotechnology on Farm-Level Economics and Sustainability; National Research Council. ISBN: 0-309-14709-3, 240 p. [Link](#). ■
- **Food Security: The Challenge of Feeding 9 Billion People.** Charles, H., J. Godfray, J.R. Beddington, I.R. Crute, L. Haddad, D. Lawrence, J.F. Muir, J. Pretty, S. Robinson, S.M. Thomas, and C. Toulmin. 2010. [Science, V. 327, 12 February](#). ■
- **Carbon Dioxide Enrichment Inhibits Nitrate Assimilation in Wheat and Arabidopsis.** Bloom, A.J., M. Burger, J.S.R. Asensio, and A.B. Cousins. 2010. [Science, V. 328, 14 May](#). ■
- **The Rational Optimist: How Prosperity Evolves.** Ridley, M. Harper. 448 p. See book review on [The Economist](#) and at [Amazon](#). ■

For more “K in the literature” go to www.ipipotash.org/literature/

Note: All abstracts in this section are published with permission from the original publisher.

IPI New Coordinator



New IPI Coordinator for sub-Saharan Africa

Mr. Olivier Goujard has been appointed as the IPI Coordinator for sub-Saharan Africa as of May 2010. With his rich experience in the field, including expertise in two different input markets, Mr. Goujard brings an excellent mix of capacities to IPI, which will enable him to coordinate the newly established IPI activities in the region. Mr. Goujard's predecessor, Dr. Georg Ebert, is now the Head of Research & Development at COMPO Germany, a subsidiary of K+S Group.

Mr. Goujard, was raised on a family farm located in the field crop growing areas of the Champagne region. After

completing his Baccalaureate degree in maths, physics, chemistry and biology, he studied agriculture for five years, achieving the diploma of "Ingénieur en Agriculture" from Ecole Supérieure d'Ingénieurs et de Techniciens pour l'Agriculture in 1995.

Mr. Goujard's professional career started in the crop protection sector. He worked first for Rhône-Poulenc Agro France, where he was responsible, as a field development technician, for setting up and conducting field trials, preparing reports and organising trial visits. In 2000, he joined Aventis CropScience (then Bayer CropScience) where, as a product development manager and then global product manager, he developed worldwide expertise in insect pests and crop protection insecticides in order to build up technical profiles for the development of new products.

Mr. Goujard joined K+S KALI in 2005, where he is the technical manager for all the company's agronomical activities in France. As part of the international team of agronomists, he also has responsibility for African markets. In addition, Mr. Goujard represents the company in key professional organizations, including as the coordinator of the sulphur working group of COMIFER (French committee

for integrated fertilization) which is the official organization responsible for fertilizer recommendations in France.

In his spare time, Mr. Goujard enjoys mountain biking and fishing. We warmly welcome him to IPI and look forward to him developing his role as our activities expand in sub-Saharan Africa.

Mr. Olivier Goujard can be contacted at olivier.goujard@ipipotash.org or olivier.goujard@kalifrance.com

c/o K+S KALI France
5, rue Gaston Boyer, F-51100 Reims
France

Tel.: +33 3 26 84 30 32

Fax: +33 3 26 84 22 01

Mobile: +33 6 89 83 06 35



Clipboard

IPI in pictures on "Flickr"

Our pictures taken in the field and at meetings are now presented on Flickr. It does allow you to use these (but please acknowledge IPI), add a comment, share, and so on as with other web tools. See this on the [IPI website](http://www.ipipotash.org). ■

Impressum e-ifc

ISSN 1662-2499 (Online); ISSN 1662-6656 (Print)

Publisher	International Potash Institute (IPI)
Editors	Ernest A. Kirkby, UK; WRENmedia, UK; Hillel Magen, IPI
Layout & design	Martha Vacano, IPI
Address	International Potash Institute P.O. Box 569 Baumgärtlistrasse 17 CH-8810 Horgen, Switzerland
Telephone	+41 43 810 49 22
Telefax	+41 43 810 49 25
E-mail	ipi@ipipotash.org
Website	www.ipipotash.org

Quarterly e-mail newsletter sent upon request and available on the IPI website.

Subscribe to the e-ifc, e-mail to: e-ifc-subscribe@ipipotash.org
(no need for subject or body text).

To unsubscribe, e-mail to: e-ifc-unsubscribe@ipipotash.org

IPI member companies:

ICL Fertilizers; JSC International Potash Company; JSC Silvinit; K+S KALI GmbH; Tessenderlo Chemie.

Copyright © International Potash Institute

IPI holds the copyright to its publications and web pages but encourages duplication of these materials for noncommercial purposes. Proper citation is requested. Permission to make digital or hard copies of this work for personal or educational use is granted without fee and without a formal request provided that copies are not made or distributed for profit or commercial use and that copies bear full citation on the first page. Copyright for components not owned by IPI must be acknowledged and permission must be required with the owner of the information.